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Reports of the Chaco Center
Number Eight

RECENT RESEARCH ON CHACO PREHISTORY

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RECENT RESEARCH ON CHACO PREHISTORY

Edited by

W. JAMES JUDGE and JOHN D. SCHELBERG

DIVISION OF CULTURAL RESEARCH

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   1977 Aerial Remote Sensing Techniques in Archeology. Reports of the Chaco Center, No. 2. National Park Service and University of New Mexico, Albuquerque.

3. POWERS, ROBERT P., WILLIAM B. GILLESPIE, AND STEPHEN H. LEKSON

   1983 The Outlier Survey: A Regional View of Settlement in the San Juan Basin. Reports of the Chaco Center, No. 3. Division of Cultural Research, National Park Service, Albuquerque.

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5. WINDES, THOMAS C.

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6. LEKSON, STEPHEN H., ED.

   1983 The Architecture and Dendrochronology of Chetro Ketl, Chaco Canyon, New Mexico. Reports of the Chaco Center, No. 6. Division of Cultural Research, National Park Service, Albuquerque.

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The Chaco Center, formally known as the Division of Cultural Research, a joint National Park Service/University of New Mexico facility, was established in 1971 to conduct multidisciplinary research in the area of Chaco Canyon, New Mexico. One of the Center's most important missions is to disseminate the results of its research to the professional community and to the interested public. Reports on research projects of the Center are issued either in the National Park Service Publications in Archeology series or in the Reports of the Chaco Center series. The latter was established in 1976 to provide economical and timely distribution of the more specialized research undertaken by the Center. This report is issued as the eighth of that series.

The Division of Cultural Research maintains an up-to-date listing of all published papers, reports, and monographs dealing with Chacoan or Chaco-related research carried out under the general auspices of the Chaco Center, regardless of where they might be published. This list, entitled "Contributions of the Chaco Center," is available on request. Correspondence should be addressed to the Archival Assistant, Division of Cultural Research, National Park Service, P.O. Box 26176, Albuquerque, New Mexico, 87125.

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INTRODUCTION

W. James Judge

This entire volume is devoted to research undertaken on the Chaco Phenomenon. Most of the papers herein were presented at two symposia sponsored by the National Park Service's Chaco Center at the Society for American Archaeology Annual Meetings in San Diego in May 1981. The symposia were titled "Past Environment and Subsistence at Chaco Canyon, New Mexico," chaired by William Gillespie, and "Chacoan Prehistory: The Implications of a Regional Perspective," chaired by myself.

The purpose of the symposia was to present an interim status report on the research being carried out in the San Juan Basin by the Chaco Center. Theoretical and methodological issues were discussed, as well as the initial results of analyses completed at the time. Research by the Chaco Center has included an inventory survey of the entire National Monument (now known as Chaco Culture National Historical Park), the excavation or testing of some 30 sites in the Canyon area, and the initial survey/reconnaissance of three of the Chaco outliers. Further analysis has been performed on Chacoan collections housed in various museums throughout the country.

It is important to point out that at the time of the symposia, analyses were still ongoing and that the results presented were truly interim in nature. Since this volume contains many of those reports, the interim character of the papers herein should be stressed also. Even though generally updated as of 1983, the basic thrust of the papers is that of the status of the Project in 1981.

Though interim in character, the papers nonetheless represent a departure from much of the published literature available on the Chaco Phenomenon. We felt it important to bring this information to the attention of colleagues who could not attend the symposia. That is the purpose of this volume, to reach a much wider audience with the information at this time.

All but 5 of the 20 papers presented in the San Diego symposia are included herein. Two that were not presented there have been added to this volume because of their relevance to the subject. All papers have been updated, that is, some changes have been incorporated that reflect ongoing analyses. Otherwise the papers are essentially the same as presented in 1981. They all speak well for themselves and need not be summarized here.

We are currently preparing final reports on the results of the Chaco Project and anticipate volumes on architecture and artifact analyses, as well as a general synthesis of project results, to be ready in the next several years. Two doctoral dissertations relating to the project have been completed, and three more are in preparation.

During the course of the project, we attempted to deal with as much existing data from Chaco Canyon as possible, not just that recovered by our own staff. Thus artifacts, burials notes, records, photos, maps, etc., from all across the country were incorporated into our analyses, to the extent they could be made available to us. This also broadens the perspective of the reports herein.

As the Chaco Project developed, the staff investigated a number of research models, including those dealing with Mesoamerican influence, indigenous growth, trade and exchange, environmental degradation, and numerous "traditional" explanations for the rise and demise of the Chaco Phenomenon. Although no single model characterized our approach, concepts of redistribution and social stratification received a good deal of attention. Debate among staff members of the Chaco Center as to the character of economic organization, degree of social complexity, extent and character of trade networks, ecological adaptation and other aspects of the Chaco Phenomenon continued throughout, at times quite vigorous, always healthy and enlightening. Thus the papers represent a variety of perspectives, views, and approaches to the problem.

Our work in the Canyon area itself is now done, but as a result of Congressional action taken in 1980 to preserve and protect the Chacoan outlier system, the Chaco Center is now authorized to continue preliminary investigations of the outliers themselves, and thus we are currently conducting survey in those areas. These data, as well as results of recent analyses of project material, present some serious challenges to the concept of redistribution as one of the primary foci of the Chacoan socioeconomic system. We are now reexamining the material with new hypotheses in mind, thankful that given a project of this length we did not commit ourselves inflexibly to a single explanatory model at the time the the research design was developed. If there is anything that the staff of the Chaco Project could agree on as a result of our efforts, it is that just as there are no simple Chacoan sites, there are no simple answers to the Chacoan problems. Perhaps there are no final answers at all.

ACKNOWLEDGMENTS

I would like to take this opportunity to gratefully acknowledge the contributions to Chacoan prehistory made by the participants in the symposia. They are listed below. I would also like to especially thank those who were members of the Chaco Center staff in 1981, without whose ideas, expertise, and enthusiasm for prehistory we would know much less about Chaco than we do today. Their contributions are genuinely appreciated.

Participants in the San Diego SAA Symposia:

Nancy Akins*
Julio Betancourt
Cathy Cameron*
Karen Clary
Ann Cully
Jack Cully
Kenneth Eggert
Bill Gillespie*
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Steve Lekson*
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ANALOGY, COMPLEXITY AND REGIONALLY-BASED PERSPECTIVES

John D. Schelberg

Abstract

Reconstructions of the social complexity and organization of the prehistoric inhabitants of Chaco Canyon place too much emphasis on arguments of analogy with the Pueblo Indians of the ethnographic present. This, and a failure to adequately consider the characteristics of the ecosystem, has resulted in a number of social reconstructions that are neither accurate nor an advancement of our understanding of the Anasazi adaptation to this stressed and unpredictable environment. At its most complex, the Chacoan society implies a hierarchy of sites with three distinct levels of complexity, perhaps related to specialized administrative control activities. This is reflected in the settlement systems and the internal organization of the sites.

Background Information

A hierarchy of settlement sizes and types is characteristic of the chiefdom or stratified level of society (Peebles and Kus 1977). The Chacoan settlement pattern in the San Juan Basin of northwestern New Mexico indicates that one such society evolved partially in response to a set of ecological conditions. The extent of its hierarchical development will be considered in relation to those conditions.

Many previous investigations of the social organization and complexity of the Chacoan Anasazi have been interpretations of past events based extensively or exclusively on analogies with the Pueblo Indians of the ethnographic present. Variations in site morphology within the canyon were considered to be the results of progressive versus conservative attitudes, personal choice, immigration, progressive change through time, or the coexistence of two different systems of social organization (Vivian 1970:60). There was general agreement that this was a tribally based egalitarian society.

More recently it was proposed that a ranked society developed within the canyon (Grebinger 1973). While this did occur it was generally not the result of the processes that were suggested. The author was relying on the available published literature, which contains numerous empirical errors. In addition, the scope of his analysis was confined to the canyon proper; and the interaction with the surrounding region was only weakly considered. Chaco was presented as a forested area surrounded by a less favorable region that could not be occupied until after the development of irrigation; however, this was not the case.

A more recent proposal concerned the development of an interaction sphere (Altschul 1978). This, too, is a reasonable proposition but again the author was working from the same published literature. In addition to a variety of empirical problems with the article, he notes that "in order to analyze the Chacoan interaction sphere it is necessary to consider its constituent parts at an egalitarian level of organization" (ibid., p. 121). One of the reasons given is that there are no known ethnographic examples of a hierarchical society (ibid., p. 135)! Such interpretations of archaeological facts in light of the ethnographic present may, and in this case does, mask fundamentally important differences between the sociopolitical organization of the Chacoan Anasazi and the Pueblo Indians. There are clear-cut similarities between the two systems; however, if we assume that there is only a one-to-one correspondence in everything then we must also assume that nothing ever changes. Binford and Binford (1968) note that, in the absence of a logically structured argument, archaeological reconstruction of excavated sociocultural systems often takes the form of a direct analogy with a comparable living system. The result is that important variables may not be considered. A more effective use of the argument of analogy is to generate ideas that may then be tested by the implications of the static remains of the archaeological record.

Environmental Characteristics

The archaeology of Chaco Canyon cannot be understood unless the relationship with the surrounding region is understood. An ecological approach should be more than a characterization of an area and should attempt to point out various ecosystemic processes that were operating in the region. The natural environment is considered to be strongly selective for the kinds of adaptive interactions that were undertaken. However, the natural environment should not necessarily be thought of as more important than the social environment.

The San Juan Basin is a semiarid area in which precipitation is highly variable with respect to time, place, and amount; however, at least some portions of the region receive moisture during any given year. There is also a tendency for good years to be good everywhere and for poor years to be poor everywhere (Noy-Mier 1973). The region is sharply seasonal and severe late spring and early fall frosts are common. The average annual precipitation is 220 mm (r=89 to 457 mm) and the average frost-free period is 110 days (r=74 to 179 days) (Schelberg 1982). Diversity is low, the environmental changes are extreme, and the ecosystem productivity is low. Such regions are slow to recover from damage because the low productivity limits their capacity for regrowth (Whittaker 1975:176).

Chaco Canyon was not a forested, well watered oasis. The climate during the Anasazi occupation was essentially the same as the climate of today (Rose 1979). In addition to the conditions of low productivity and low stability, the daily interaction of the Chacoans with their environment could have both severely degraded and overexploited it in a relatively short time.

Organizational Characteristics

Some ecologists and archaeologists have argued that increased community complexity produced community stability; however, May (1973) demonstrates that it is environmental stability that allows the evolution of community complexity. Any system evolving in an unstable environment should be relatively simple and dynamically robust to be better able to survive perturbations to either the environment or the population. On the one hand many ecologists make a convincing case for increased systemic complexity in order to process energy more efficiently. On the other, May (1975) demonstrates that with increasing interdependence and complexity a system becomes increasingly fragile and less able to survive perturbations to itself or its environment. As the Chacoans became increasingly complex and interdependent they became increasingly dynamically fragile and less able to withstand perturbations.

The increased complexity of the Chacoans was the result of a combination of technological and social adaptations that can be thought of as attempts to maintain stability. The degree of organization reflects the limited technology, the character of the environment, and the distribution of the resources in relation to the population. The relatively short duration of the period of maximal complexity (less than 75 years) attests to the unpredictability of the environment and the difficulties associated with maintaining interaction throughout the vast area of the San Juan Basin. I have suggested (Schelberg 1982) that similar regionally based social conventions were followed by the Basketmakers in Chaco for many of the same reasons, and that the organizational differences between them and the later Chacoans was largely one of degree rather than kind.

For agriculturalists, one response to the vagaries of such an environment is an interacting population scattered throughout the region. Agriculture that is dependent on only solar energy cannot support unlimited growth; eventually change in technology (e.g., fertilization) or higher yielding crops are necessary. Each incremental increase in social complexity costs proportionately more in terms of overall energy expenditure, and the resultant structure is more difficult to support (Odum 1971).

Increased social complexity allows for an increase in the quantity, quality, and complexity of information that can be processed by the cultural system as a whole. System-wide response to regional or local problems such as drought or crop failure can be coordinated and responded to more quickly (Peebles and Kus 1977:430). The more uncertain and risky the environment, the more advantages there are to increased social complexity. However, such an environment is the least likely to be able to support a complex system unless the system is able to expand and incorporate technological innovations.

Sahlins, Service, Fried and many others have discussed increasing social complexity from an evolutionary perspective and have generally concentrated on the relationships of the integrative mechanisms at the differing levels of complexity. There are many arguments concerning not only the characteristics of each level but even the names of the levels. Fried notes "...that tribe figures predominately on the list of putative technical terms ranked in order of ambiguity as reflected in multifarious definitions" (1968:4-5). Tringham has advocated getting rid of the term "chiefdom" because it is conceived too broadly (1974:88). Yet Fried considers the chiefdom level as "bearing the weight of evolutionary advance" because it bridges a previous level of organization--the acephalous society--with the state (1968:1-5). The origin of ranking and its effects on society is an important question.

One of the most frequently discussed aspects of chiefdoms that differentiates them from tribes is the economic basis for status distinction in which certain adults have differential access to certain resources. Redistribution is frequently cited as the hallmark of a chiefdom; however, Peebles and Kus (1977:423), whose interests are information flow and regulatory decision making, question the constant correlation of redistribution with chiefdoms and cogently point out that this concept has been applied to every situation from leveling mechanisms to buffers against environmental vagaries. This is neither a univariate phenomenon nor necessarily a causal factor. It should be noted that while they have determined, on the basis of ethnographic analysis, that redistribution is not everywhere associated with chiefdoms, they have not indicated under what conditions it is a viable alternative or when or where we might expect its occurrence.

Compared to the network structure of egalitarian societies, chiefdoms exhibit loosely coupled, two-level hierarchies of ritual control, which allow for increased flexibility, more rapid response to changing situations, and an increase in the quantity and complexity of information that can be processed by the cultural system. More and larger residential groups can be integrated into a single cultural system; increased production can be rationalized; part-time craft specialization can be supported, and buffering of environmental fluctuations can be centralized (ibid., p.428-430).

Wright and Johnson (1975) are concerned with information flow and decision making for both chiefdoms and states. A state is a society with specialized administrative (i.e., control) activites and has centralized decision-making processes that are regulated and internally specialized. The central process is divisible into separate activities that can be performed in different places at different times (ibid., p.283). There is a hierarchy of control involving at least three levels: the lowest is directly involved in production and transfer, the middle level coordinates these activities and corrects their errors, and the highest is concerned with coordinating and correcting the actions of the second level. The effectiveness of this hierarchy of control is facilitated by specialization of information processing into the categories of observation, summarizing, message transmission, information storing, and the actual decision making. This undercuts the independence of subordinates (ibid., p.267).

Simon notes that complexity frequently takes the form of a hierarchy and that hierarchic systems have some common properties that are independent of their specific content. A complex system is one made up of a large number of parts interacting in a nonsimple (i.e., nonadditive) way. A hierarchic system is one composed of interrelated subsystems each of which is, in turn, hierarchic in structure until some lowest level is reached. The lowest level is generally arbitrary and varies with the intent of the analysis (1969:84-88).

The Rank-Size Rule

Given the character of archaeological data, especially on a regional basis, the most frequently utilized parameters for an investigation into site hierarchies are the areas or volumes of sites and the internal configuration of those public spaces that are thought to be related to the economy and to aspects of political or religious control. One technique useful for pattern recognition is the rank-size rule, which is actually an empirical generalization (Blanton 1976; Johnson 1977) specifying the "ideal" size ratio among sites belonging to a single system in which many factors affect size (Brown and others 1978). It has been noted by a number of archaeologists that rank-size analysis of a regional settlement system can be used to assess the degree of economic development and the overall structure of the system (e.g., the presence of a primate center). It can also be used as a method that would point out such problems as the inclusion of noncontemporaneous sites or settlements from a differing cultural group.

A comparison of the actual rank order with the expected rank order on a double-log graph generally produces one of three curves. A concave slope indicates the operation of a single underlying factor, such as the presence of a primate center. A strongly concave slope with all of the sites accounted for is indicative of strong centralized control. A convex slope indicates heterogenous factors such as sites from several different settlement systems (Johnson 1977, 1981).

The rank-size distribution for a region is log-normal (i.e., linear) if it corresponds to the rank-size rule. The presence of a linear relationship suggests that operationally effective settlement system boundaries have been identified (Johnson 1977:499). A linear slope is consistent with a functional hierarchy of central places. Initially this seems contradictory because rank-size distributions are continuous and central-place distributions are discontinuous; however, Smith (in Johnson 1977:499) notes that the combination of such factors as variations in population density or demand or landscape irregularities shift the centers out of line with one another even though they might be identical with respect to regional central-place functions. Arguments concerning the meaning of a linear relationship vary; however, the stochastic processes of differential population size and demand, and environmental processes were involved. It also indicates a close fit between the scale of the region surveyed and the spatial extent of the economic system operating at that time (Johnson 1977:499).

Chacoan Sites

Following Brown and others (1978) and Turner and others (1981) I will briefly assess several aspects of the Chacoan settlement pattern in order to illustrate the hierarchy of sites and the number of levels that were potentially involved. Powers and others (1981) estimate the enclosed site area for a sample of 52 of the over 70 known Chacoan great houses that occur throughout the San Juan Basin. Where a definable plaza existed its area is included. Figure 1 and Table 1 indicate a tremendous range in size from less than 200 m^2 to over 23,000 m^2. There are three obvious groupings in Figure 1. Powers and others (1981) call these extra large, large, and medium to small and suggest that a three-level hierarchy existed within the great houses.

I am going to suggest that, with a few exceptions, the size of the great house was a reflection of its primary function, such as an elite residence, its importance within the social network, and the size of its surrounding community. The latter is partially a reflection of local environmental productivity. Therefore, Figure 1 only indicates the two highest levels of the hierarchy. The third level is the villages surrounding their respective great house, but there is very little information available concerning them.

Figure 2 is the rank order of the Chacoan great houses (total=67; Table 1). It includes an additional 15 sites not included in the histogram and is relatively linear. The inclusion of the 15 extra sites increases the linearity. Figure 3 is the rank order of the sites displayed in Figure 1. Because not all of the great houses have been included or even located, this graph is only an approximation and should be viewed as an initial assessment. As more are located by future surveys (we are not expecting any more extra-large or large ones) the fall off will become less marked.

One important point is that the slope is not concave indicating that none of the sites, as plotted, functioned as a primate center, as conceived by economists and others. The absence of a primate center and an uncommercialized economy are very much in keeping with the regional interaction as an extensive coping strategy in a risky environment.

Chaco Canyon is but a small portion of the San Juan Basin. A case could be made that the site areas of functionally

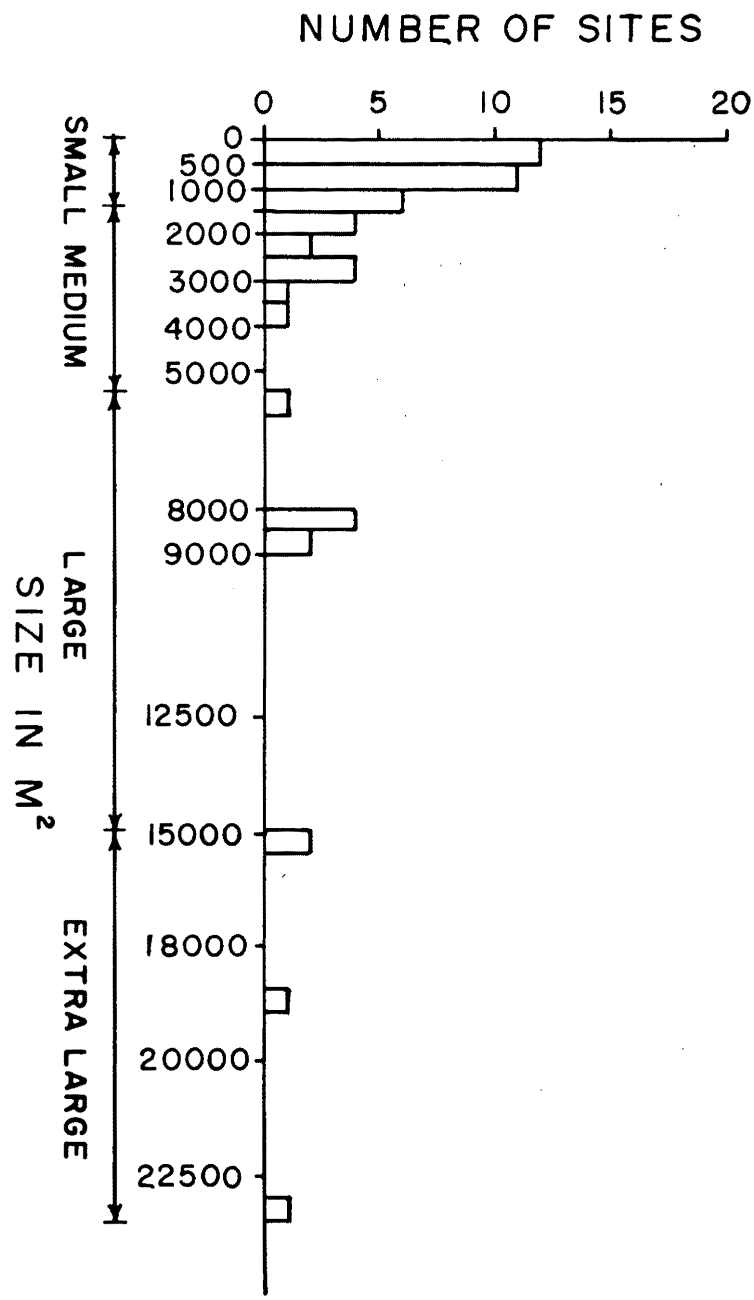

Figure 1. Site area of 52 Chacoan great houses located in Chaco Canyon and the San Juan Basin.

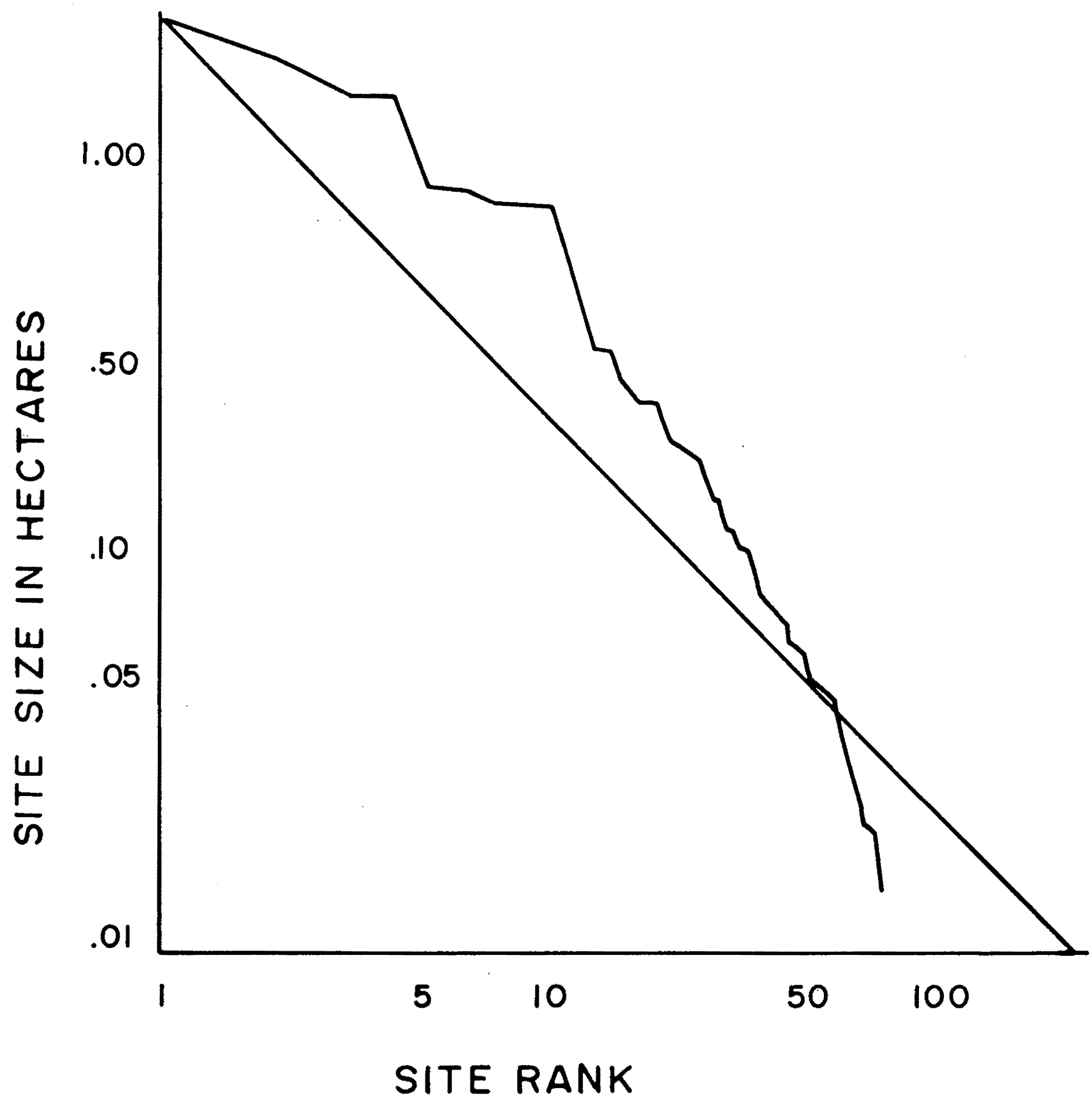

Figure 2. Rank order for 67 Chacoan great houses located in Chaco Canyon and the San Juan Basin.

TABLE 1. The rank, area, number of Great Kivas and estimated number of rooms for Chacoan Great Houses in the San Juan Basin.

Rank	Site Name	Area (m^2)	Great Kivas	Rooms	Reference
1	Chetro Ketl *	23,395	2	580+	P
2	Pueblo Bonito *	18,530	3	695+	P
3	Aztec Ruin	15,031	1	450+	P
4	Penasco Blanco *	15,010	4	215+	P
5	Pueblo del Arroyo *	8,990	1 ?	290+	P
6	Una Vida *	8,750	2 ?	160+	P
7	Salmon Ruin	8,320	1	175+	P
8	Pueblo Alto *	8,260		120+	P
9	Kin Bineola	8,225	1 ?	230+	P
10	Hungo Pavi *	8,025	1	150+	P
11	Pueblo Pintado	5,935	1 ?	135+	P
12	San Mateo	4,125		95-112	M
13	Tsin Kletzin *	3,440		155+	P
14	Allantown, Ariz.	3,460	1	100+	P
15	Morris' Site 41	2,875	1	75+	P
16	Kin Kletso *	2,640		135+	P
17	Wijiji *	2,535		190+	P
18	Chimney Rock, Col.	2,535		55+	P
19	Kin Klizhin	2,395		18+	P
20	Haystack	2,055	1	26+	P
21	Skunk Springs	1,935	1	45+	P
22	Peach Springs	1,880	1	25+	P
23	Kin Ya-a	1,845		44+	P
24	Great Bend	1,800		13++	M
25	Sterling Site	1,685		25+	P
26	Casa Chiquita *	1,460		80	P
27	Guadalupe	1,400		25+	P
28	Casa del Rio	1,250		125-130	M
29	Muddy Water	1,205		25+	P
30	Yucca House, Col.	1,190		40+	P
31	Wallace Ruin, Col.	1,080		73+	P
32	Bis sa'ani	1,040		37+	P
33	Newcomb	1,000	1 ?	13+	M
34	Lowry Ruin, Col.	870	1	34+	P
35	Dalton Pass	825	1	20+	P
36	Toh La Kai	800	1	25+	M
37	El Rito	795	1	55+	P
38	Andrews	750	1	5+	M
39	Morris' Site 39	730		40	P
40	Ida Jean, Col.	695	1	55+	P
41	Coolidge	680	1	21	M
42	New Alto *	645		51+	P
43	Casa Mero	635	1	26+	P
44	Standing Rock	630		35+	P
45	Vil. of the Grt. Kivas	590	1	18	P

TABLE 1 (continued).

Rank	Site Name	Area (m^2)	Great kivas	Rooms	Reference
46	Muddy Water Site 1	575		22	P
47	Kin Nizhoni	550		14	M
48	Pierre's # 6	505		18+	P
49	Whirlwind House	500		18+	M
50	Coyotes Sing Here	500		20+	M
51	Upper Kin Klizhin	470		25+	P
52	Twin Angles	470		17+	P
53	Escalante, Col.	455		25	P
54	Bee Burrow	452		11	P
55	Muddy Water	390		7	P
56	Sanostee	325	1	9	M
57	Pierre's House B	315		13	P
58	Section 8	280		7+	M
59	Pierre's House A	255		15+	P
60	Greenlee Ruin	255		15+	P
61	Casa Abajo	250		9+	M
62	Lake Valley # 2	230		14+	M
63	Grey Hills Springs	215		1	P
64	Hogback Ruin	205		10+	P
65	Houck Ruin, Ariz.	200		9+	P
66	Casa Cielo	200		12+	M
67	Halfway House	145		12+	P

* the site is located in Chaco Canyon
sources: P Powers and others 1981
M Marshall and others 1979

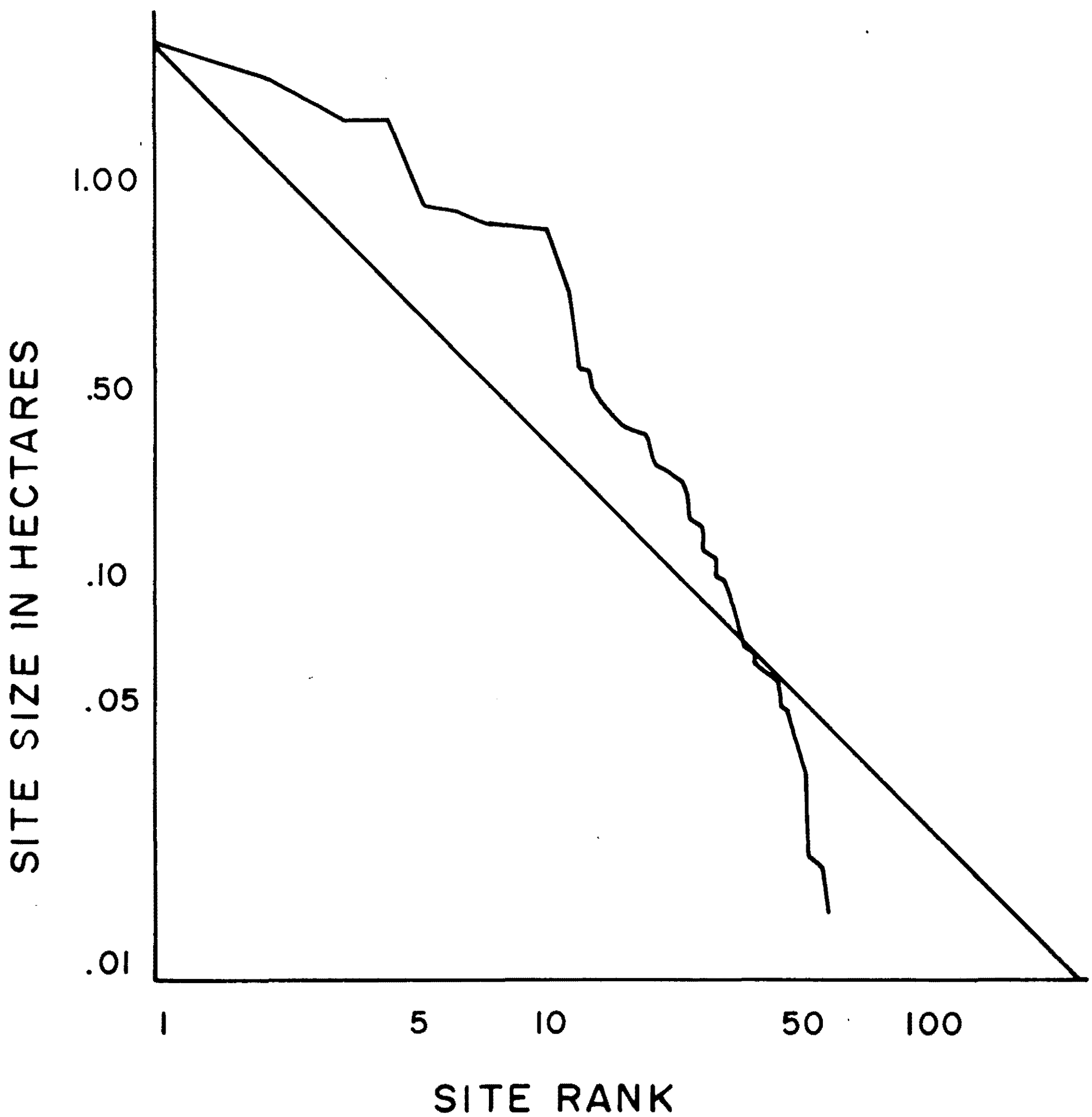

Figure 3. Rank order for 52 Chacoan great houses.

equivalent great houses in the canyon could be combined. Doing so with Pueblo Bonito and Chetro Ketl does not produce a strongly concave slope (Figure 4). Many other combinations could be considered but that is beyond the scope of this paper, especially given the current state of knowledge concerning the sites throughout the region.

While these four pueblos could be considered as a unit with respect to other great houses in the canyon, their internal configurations are not sufficiently different to warrant placing them in a qualitatively separate category of economic primate center. With the exception of the presence or absence of a great kiva, these sites appear to be similarly organized and essentially repetitive without a division into functionally specialized units. This is not what one expects to find in cities (e.g., Teotihuacan, Sanders and others 1979) or in primate centers in certain environments (e.g., Moundville, Peebles 1978). The full range of sites in Chaco (e.g., great houses, villages, isolated kivas) must be considered when comparisons are made between Chaco and the San Juan Basin. At best, a case could be made for incipient urbanism in the canyon if the full range of site variability is considered, but this is beyond the scope of this paper. Chaco Canyon probably did not function as an economic central-place; nevertheless, this does not preclude the centralization of sociopolitical activities within the canyon (Taylor 1975).

Complexity Of The Hierarchy

The number of hierarchical levels is one measure of the complexity of the system, and as previously noted, is thought to be equivalent to the number of levels of information processing required to coordinate social and subsistence interaction (Brown and others 1978). Taylor (1975) has demonstrated that the population of the political hinterland influenced by the political center and the extent of the functions that were centrally performed are closely related to the size of the center. Only those societies that have more than one level of supralocal control had a hierarchy of settlement types. There are several complementary methods with which to assess the complexity of hierarchies. The first is by the number of distinct types of civic-ceremonial structures. The principle underlying this is that ranks within a hierarchy are defined by a cumulative set of components, which means that a higher site class has most of the "distinctive features" typical of the lower class plus some feature found only at that level. Distinctive features reflect the range of goods and services available at various levels of a hierarchy (Earle 1976:207).

The second indicator of a hierarchy is the presence of organizational differences at the higher levels. This is indicated by recombinations of the characteristics of civic-ceremonial structures found at lower levels rather than a simple mechanical addition of these structures to a site (Brown and others 1978: 185). This will serve to differentiate Chacoan structures that have several plazas and/or great kivas. Kivas and plazas were the loci of ceremonial functions. Small kivas are assumed to be for restricted segments of society and great kivas are assumed to have been for the society at large. There is usually an economic component associated with ritual occasions. Food and other items exchange hands. Society-wide gatherings bring people from diverse areas together.

The lowest or first-order level is defined as the villages of the communities. Kivas are present in most villages; the number of kivas is determined by the number of residence or work units and perhaps the number of sodalities. They are relatively small (about 4 m in diameter) and their internal features include a firepit, deflector, roof supports, a few miscellaneous pits, and perhaps a few wall niches. Essentially these are what is thought of as "normal" Anasazi kivas. Plazas are present as undifferentiated and unbounded exterior work areas. Any recognizable surface would have resulted from daily activities.

At the second-order level (i.e., certain great houses), we expect to find features of the first level, new features, and different arrangements of the components. Kivas (often called Chaco-type kivas) associated with the great houses are larger (often 7-9 m in diameter) and are sometimes incorporated into room blocks. Features include those found in the village kivas; however, their arrangements are different and there are new ones. Usually there were subfloor vent shafts, masonry lined firepits, six to eight horizontal log

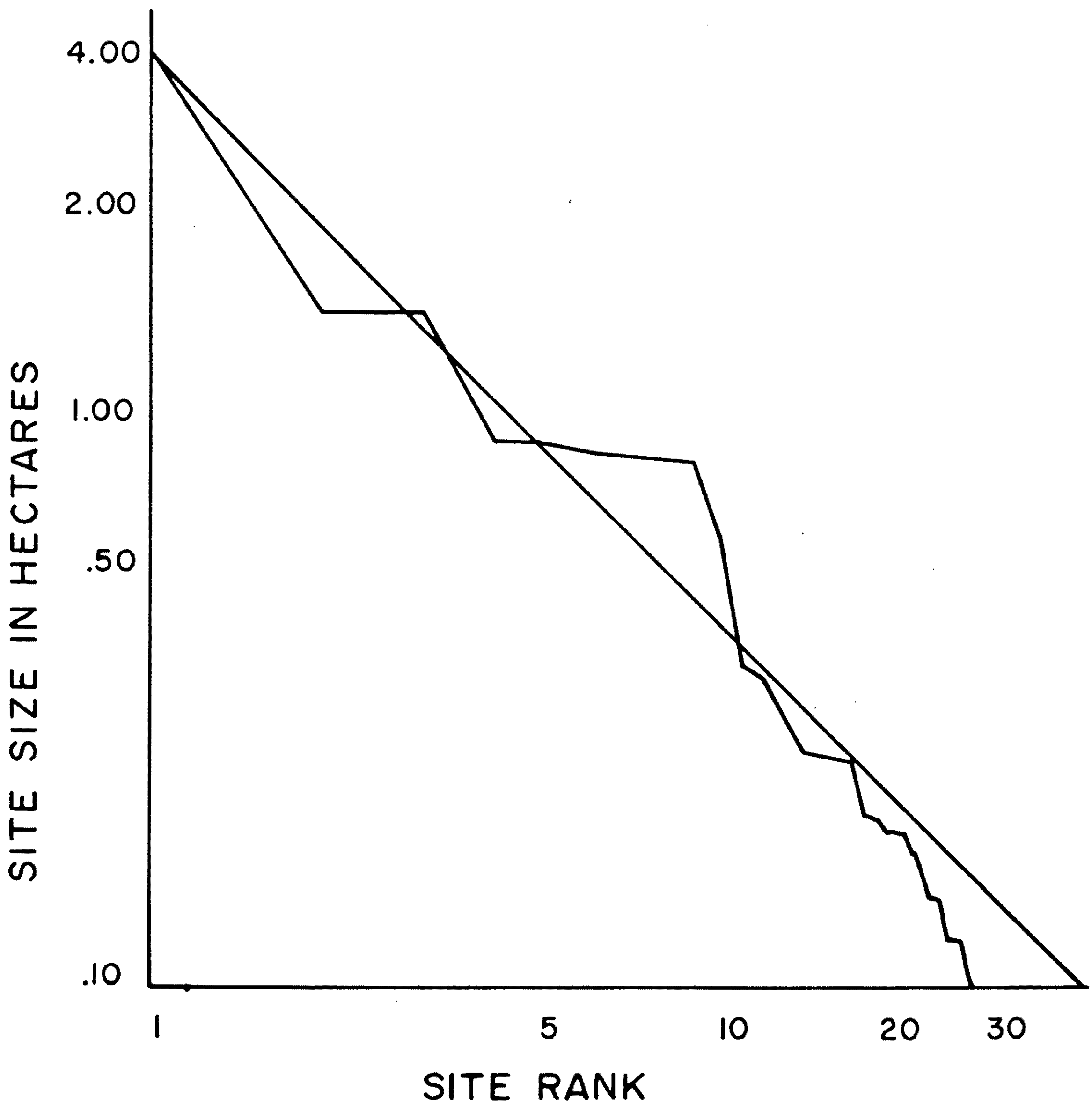

Figure 4. Rank order combining the areas of Pueblo Bonito and Chetro Ketl.

pilasters on a low bench, and a cribbed roof; there was often a southern bench recess, and a few have a floor vault. Of course, some of these features are found in an occasional small kiva. The ratio of rooms to kivas is much lower; however, this may still be proportional to the number of residence units.

Plazas are present and are often partially or completely enclosed by a wall. Specific characteristics of most of the plazas from this hierarchical level are generally unknown. However, the central plaza at Pueblo Alto was very interesting. Of the eight definable plaza surfaces in its western portion, four or five covered an area of at least 1000 m^2 and were not only constructed but were plastered. Intentional fill or debris from construction was deposited and capped off by a several centimeter thick layer of clay and sand, which formed a structural base that was then plastered with several millimeters of clay. Five surfaces occurred within an 80-cm depth and less than 75 years are thought to be involved. This type of behavior is usually associated with the interiors of rooms and not in an area that was open and exposed to the elements. During at least part of this time the floors of the rooms were simply unplastered, hard packed sand. Clearly major energy expenditures were taking place in this part of the interior plaza at Pueblo Alto (Schelberg 1982). There were also multiple surfaces in a portion of the plaza at Salmon Ruin, an outlying site essentially the same size as Pueblo Alto (Cynthia Irwin-Williams, personal communication).

A new feature found at some of the second-order sites is the great kiva (Table 1). Great kivas are distinguished by their large diameters, massive four-post or masonry column roof supports, raised masonry fire boxes, multiple masonry floor vaults, regularly patterned wall niches circling the structure, one or more benches, and attached rooms that open into it (Vivian and Reiter 1965).

The sites within this level of the hierarchy can be differentiated by the location of the great kiva; as noted, this may be an organizational characteristic. With one exception all of the great kivas at the small to medium great house sites (Table 1:29-67 and 12-28, respectively) are adjacent to or in the vicinity of the great house. Several outlying communities have more than one, as do several great houses in the canyon. At the outliers, multiple great kivas were in proximity to the Chacoan great house or scattered throughout the community. In the canyon multiple great kivas were usually located in the plaza and existing structures were modified as necessary in order to accommodate them. Simple mechanical addition seems to have been more common at the outliers than within the central canyon.

Two of the "large" great houses (Table 1:5-11) do not have great kivas--Pueblo Alto and Pueblo del Arroyo. These are both in the central Chaco area, and in proximity to Pueblo Bonito and Chetro Ketl. This cluster of sites may have interacted such that Pueblo Alto and Pueblo del Arroyo had special functions that did not require the presence of a great kiva. Certainly the elaborate plaza surfaces at Pueblo Alto imply community-wide interaction of a religious or economic nature. From the perspective of the recipient, the integrating aspects of plazas and great kivas are essentially the same. This does not imply that differing segments of society may not have been involved if the activities were taking place in more confined great kivas or in the more open plazas.

Three of the remaining five "large" sites had a single great kiva within the plaza, and the outliers of Kin Bineola and Pueblo Pintado may have one each. Three of these sites, Kin Bineola, Pueblo Pintado, and Salmon Ruin, are outliers and are associated with communities. Kin Bineola has an enclosed plaza and is one of the earliest great houses. The other two sites in this class are Una Vida and Hungo Pavi. Una Vida is another of the earliest Chacoan structures. By virtue of its association with this level of the hierarchy, the presence of a great kiva in the plaza and another nearby, and its geographical location in Chaco, it is reasonable to suggest that its primary function could have been essentially the same as the function of an outlying great house such as Kin Bineola--interacting with a surrounding community.

In the highest, or third-order level (Table 1:1-4), specific differences include the presence of one or more great kivas in the enclosed plaza. Of the four sites making up the highest order, the three in the canyon each have two great kivas enclosed in their plazas. The one that does not is the only outlier in this category, Aztec Ruin. Penasco Blanco has two additional great kivas outside of its perimeter. As one of the earliest great houses, its primary function could have been similar to that of an outlying great house interacting with a village community, as was suggested for Una Vida. Thus, there could have been a central group consisting of Pueblo Bonito, Pueblo Alto, Pueblo del Arroyo, and Chetro Ketl flanked by Una Vida, Penasco Blanco, and perhaps Hungo Pavi, the latter three functioning with villages in essentially the same manner as the outliers.

There is an additional class of sites that has not yet been discussed but which could have functioned as a very low level of the site hierarchy within the overall system (resulting in a four-level hierarchy). These consist of small scattered villages located throughout the San Juan Basin that are not in immediate proximity to outlying Chacoan great houses. Isolated kivas also exist and could have functioned as focal points for these villages. As previously mentioned, the lowest level of the hierarchy identified for analysis is arbitrary and varies with the intent of the analysis. In this case it is necessary to recognize the existence of these low-level sites and the need for inclusion in future San Juan Basin research.

Discussion

Following Wright and Johnson (1975), the first order, or the villages of an outlying community, was the residence of those who were directly involved in the daily subsistence activities. The second-order level, represented by the personages living in the "outlying" Chacoan great houses (including Penasco Blanco and Una Vida), was concerned with coordinating localized activities of the first order and attempting to control for such problems as local droughts or crop failure. The third order, or the central canyon proper (Pueblo Bonito, Pueblo Alto, Pueblo del Arroyo, and Chetro Ketl), was involved in coordinating the activities of the second-order centers and attempting to correct for region-wide problems. While the Chacoan settlement pattern appears to be similar to that discussed by Wright and Johnson (who were concerned with state-level societies), this is largely a function of adaptations to similar environments and is not because of a similar level of complexity. The Chacoan complexity was similar to that of a chiefdom. Clearly the study of ecological and social factors as they relate to spatial patterning is necessary.

Even though an economic label is used to characterize the dominant or most important mode of exchange (e.g., market or redistribution), this does not mean that this was the only transaction. Even in a market economy, redistribution, barter, and reciprocity occur. The residents of the first order or villages were probably interrelated family groups acting in reciprocal relations. They may have acted as redistributors with the personages in the Chacoan great houses either on an annual basis or in a time of local crisis. There is no a priori reason to assume that there was continuous economic transaction between the various orders of sites. Storage capacities at the villages may have sufficed for normal conditions, and it was only when a local problem arose that it would be necessary to rely on the increased storage capacity of the Chacoan structure.

Exactly the same relationship would hold between the "outlying" Chacoan great houses and the central canyon. That is, interaction occurred on an annual basis (calendrical rituals) or during time of crisis (critical rituals) (Ford 1972), or perhaps, primarily between elites only (Smith 1976). The networks existed because of the risky environment, and may have been intensively operationalized only during periods of deprivation.

Many of the outlying areas show in situ growth from Basketmaker time onward. Some may have been founded after the inception of the Chacoan system, but the majority were not the result of a supposed population explosion within the canyon (as implied by Grebinger and Altschul). This should be clarified in the future as careful survey and testing of the outlying great houses and communities occur. To date, survey at the outliers has been nonsystematic or in arbitrarily predetermined areas. Before a detailed analysis can be completed, several communities must be surveyed in their entirety.

Unfortunately classificatory labels frequently evoke passioned response rather than reasoned debate. It should be remembered that urbanism, stratification, and complex social development are processes and not fixed points on linear scales, even though we discuss them as points for the sake of simplifying communication. Suggestions of incipient urbanism, stratification or a complex chiefdom are not simple attempts to overextol the virtues of Chaco or to make the development comparable in grandeur to other areas of the world. It is an attempt, however, to indicate that certain processes had occurred. Even the decline in social complexity conforms to generalizations derived from cross-cultural studies. It is frequently noted that complex chiefdoms last only 50 to 100 years before they either "collapse" or become states. The most complex development of the Chacoans lasted less than 75 years. The commonality between Chaco and certain other areas of complex social development may be the conditions that selected for those processes and not the physical manifestations.

Thus, there was a three- or perhaps even four-level hierarchical adaptation of the Chacoan Anasazi in the San Juan Basin. Arguments concerning classificatory labels such as "complex chiefdom" (which I believe the Chacoans to have been) or "simple state" obscure the more important question concerning the conditions that select for stratification. Stratified societies have evolved in many areas of the world and there is no reason to assume a single causality. However, some of them may have been the result of an attempt to adapt more efficiently to stressed semiarid environments of low productivity and low predictability because of the necessity to monitor a wide range of variables and to coordinate the activites and responses of many people.

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REGIONAL INTERACTION IN THE SAN JUAN BASIN: THE CHACOAN OUTLIER SYSTEM

Robert P. Powers

Abstract

The presence of numerous communities with an associated Chacoan structure, the road linkage of many of these communities, and a size hierarchy of Chacoan structures suggest the evolution of a complex cultural system within the San Juan Basin during the tenth to twelfth centuries. The large sites in Chaco Canyon may be identified as regional centers of the system. Differential resource distribution and the unpredictability of annual precipitation over the expanse of the semi-arid San Juan Basin suggest that the impetus for interaction was at least partially economic. Exchange of ceramic and lithic materials did occur, but present evidence suggests that major quantities of certain exchange goods were consumed in Chaco Canyon rather than redistributed. A range of possible goods and services that Chaco Canyon may have provided in exchange for consumed goods is suggested.

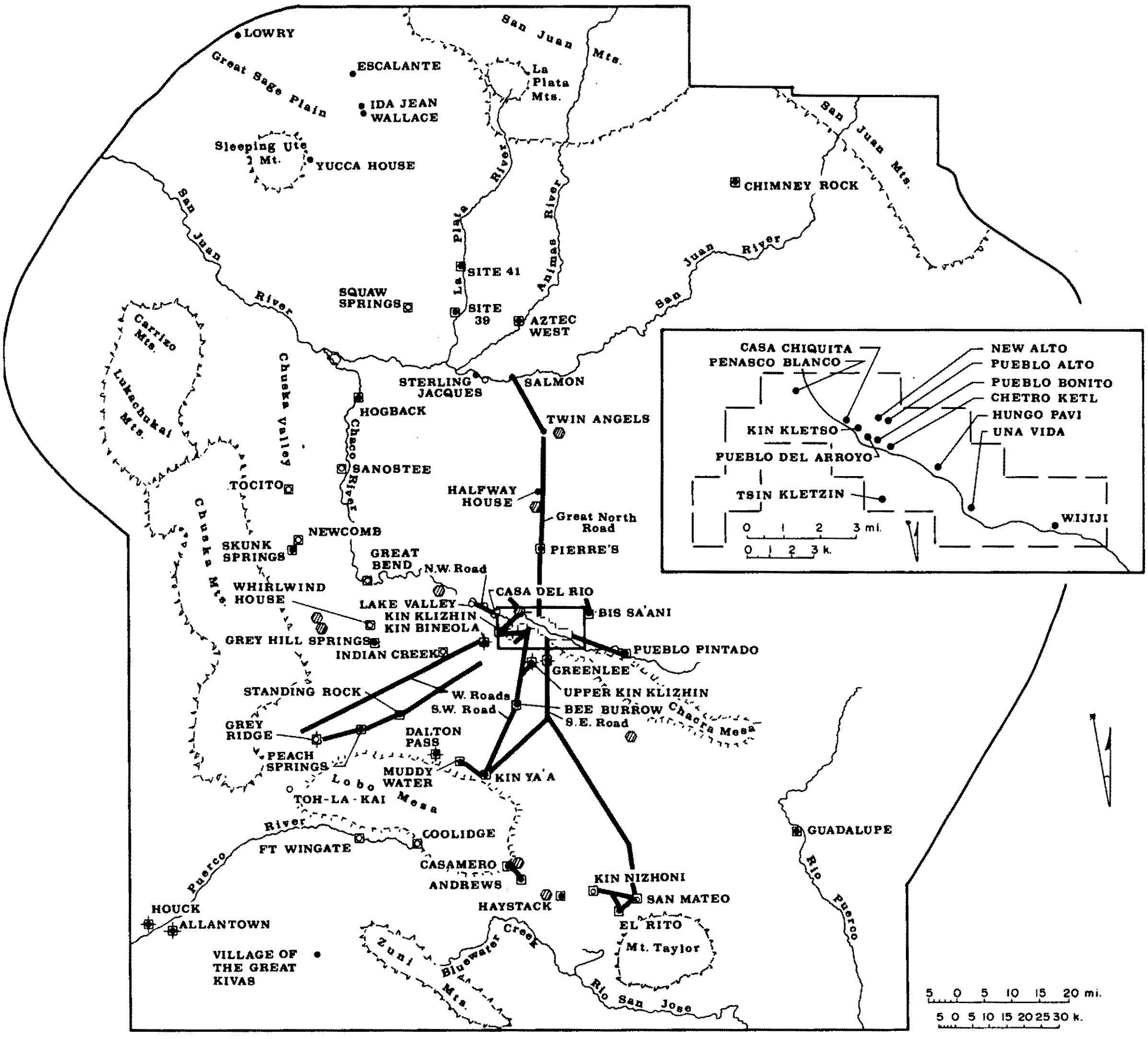
Introduction

The purpose of this paper is to summarize National Park Service research on Chacoan outliers in the San Juan Basin of northwestern New Mexico. The data and conclusions presented here are summarial in nature, but are presented in much greater detail in a recent monograph (Powers and others 1983).

The San Juan Basin as referred to herein is a large (ca. 85,000 km^2) structural feature bounded topographically on the north by the San Juan Mountains and the Dolores River, on the west by the Chuska Mountains, on the south by the Zuni Mountains, and on the east by the Nacimiento Mountains and the Hogback Monocline. In the south and east portion of this area is the smaller Chaco Basin (11,500 km^2), an area defined by the extent of the Chaco River and its tributaries (Figure 1). Outside of Chaco Canyon, yet within the larger San Juan Basin, the presence of contemporary sites exhibiting architecture and, in some instances, ceramic types characteristic of Chaco Canyon has long been noted. Explanations of the purpose of such sites, including Chimney Rock Pueblo (Jeancon and Roberts 1924; Eddy 1977), Lowry Ruin (Martin 1936), Aztec (Morris 1928), Village of the Great Kivas (Roberts 1932), and Guadalupe (Pippin 1979) among others, have been debated for over 50 years. More recently it has become apparent that there are dozens of such sites throughout the San Juan Basin; many occur within major site aggregations or communities and are linked to the Chaco Canyon sites via prehistoric roadways. The term Chacoan outlier is used herein to refer to all such sites occurring outside Chaco Canyon.

In order to determine the nature of outlier interaction with the Chaco Canyon sites, an archaeological survey of three outlier communities was undertaken in 1976, followed by supplementary reconnaissance at additional outlier communities. This effort was complemented by a literature search of these and additional outlying sites. Subsequent analysis and write-up of this cumulative sample of 35 outliers has recently been completed (Powers and others 1983). The study was by no means a comprehensive inventory of all outlier communities since other investigations, particularly that by Marshall and others (1979), have documented a large number of additional outliers. To date many more sites have undoubtedly escaped description and interpretation by archaeologists.

Since the investigation of outlying sites was in many ways a ground breaking effort, a study focusing on one narrowly defined research problem was not felt to be appropriate; rather, a more general approach was adopted. The result was a combined analysis of site chronology, settlement pattern, environment, site morphology, and surface artifact remains from community, road system, and regional levels, in an attempt to determine how a regional interaction system evolved. While this effort is far from complete, a much broader-based understanding of the Chacoan outlier system is now possible.



- OUTLYING CHACOAN STRUCTURE OR MAJOR CHACO CANYON STRUCTURE (TREATED IN THIS STUDY)
- OUTLYING CHACOAN STRUCTURE (NOT TREATED IN THIS STUDY)
- OUTLYING CHACOAN STRUCTURE AND ASSOCIATED COMMUNITY (INNER CIRCLE OR DOT KEYS TREATMENT OR NON-TREATMENT)
- OUTLYING CHACOAN STRUCTURE AND PROBABLE ASSOCIATED COMMUNITY (INNER CIRCLE OR DOT KEYS TREATMENT OR NON-TREATMENT)
- OTHER RECONNAISSANCE AREA
- SCHEMATIC INTERPRETATION OF PROBABLE PREHISTORIC ROAD. WITH THE EXCEPTION OF THE GREAT NORTH ROAD AND THE SOUTHWEST ROAD, ROAD IDENTIFICATIONS ARE TENTATIVE, SUBJECT TO FUTURE CONFIRMATION THROUGH GROUND SURVEY.

INTENSIVE SURVEY AREAS INCLUDE THE BIS SA'ANI, PEACH SPRINGS, AND PIERRE'S COMMUNITIES. RECONNAISSANCE AREAS INCLUDE THE TWIN ANGELS, HALFWAY HOUSE, HOGBACK, GREAT BEND, GREY HILL SPRINGS, STANDING ROCK, DALTON PASS, MUDDY WATER, AND CASAMERO OUTLYING STRUCTURES OR COMMUNITIES.

Figure 1. The Chacoan System at the peak of development during Early Pueblo III (A.D. 1050-1175).

Chronology

The study results show that the first outlying communities, defined by the presence of a Chacoan structure and a minimum of eight contemporary residential pueblos or small-house sites within an eight square kilometer area, are present in locations ringing the Chaco Basin edges by A.D. 900-975 (Figure 1 and Table 1). Community establishment continued at a moderate pace until the last quarter of the eleventh century when a tremendous surge of construction activity, lasting until approximately A.D. 1140, occurred. All building, as determined from tree-ring dated construction timbers, appears to cease by this date. Abandonment may have begun almost immediately, but limited occupation continued at a reduced number of outliers until the first quarter of the thirteenth century. It is clear that by A.D. 1175 the Chacoan system and the outliers within it had ceased to function in any coordinated fashion.

Site Types

Prior to A.D. 900, the types of sites in the San Juan Basin are limited to small masonry habitation pueblos with pithouses, a variety of special-use sites such as hunting or gathering camps and fieldhouses, and occasional great kivas. During the A.D. 900-975 period, however, another site type, here termed the Chacoan structure, becomes recognizable (Table 1). These sites, also referred to in the literature as towns (Vivian and Mathew 1965; Vivian 1970a, 1970b) or greathouses (Morris 1928, 1939) have architectural attributes most frequently including large-scale planning, compound or core and veneer Chaco-style masonry, large rooms, and Chaco-style kivas (Vivian 1970a, 1970b; Powers and others 1983). Other less consistently occurring features, including great kivas, multiple stories, tower kivas, and enclosed plazas are present at some sites, but their presence or absence appears to be more directly related to site size or function.

It is important to emphasize that the term Chacoan structure is used only in an architectural and stylistic sense. It does not imply the ethnic or cultural affiliation of the population in the surrounding community. For example, at the Chimney Rock outlier community some 135 km northeast of Chaco Canyon, it is debatable whether or not Chimney Rock Pueblo, a Chacoan structure, was occupied by Chacoan immigrants as argued by Eddy (1977). There is little question that the occupants of the surrounding small-house sites represent a local, indigenous population whose progenitors had resided in the area since Pueblo I times (Roberts 1930).

Roads

As the result of aerial imagery analyses and road identification field studies (Vivian 1972; Lyons and Hitchcock 1977; Ware and Gumerman 1977; Obenauf 1980; Kincaid 1983), it is apparent that many of the outliers in the Chaco Basin are linked to one of five major road systems that interconnect at Chaco Canyon (Figure 1). More distant outliers may also prove to be road-linked, but the lack of studies in peripheral areas prohibit conclusions. The identification of many portions of these road systems remains tentative, pending further fieldwork; and, similarly, road chronology is also uncertain. However, the consistent association of roads with Chaco structures leaves little doubt that the roads were constructed for use prior to the A.D. 1150-1175 collapse. Perhaps most importantly, the major roads enter Chaco Canyon near the locations of several of the large- and medium-size Chacoan structures--suggesting that these canyon sites may have controlled road traffic and goods movement, and therefore to some degree, the sites associated with each road system.

Size Hierarchy Of Chacoan Structures

Although the development of a Chacoan structure size hierarchy over the A.D. 900-1140 period cannot yet be fully detailed, it is apparent that by the latter date distinct size and morphological attributes provide a solid basis for proposing a three level (large, medium, small) size hierarchy (Table 2) with correlating functional distinctions.

The four large Chacoan structures ($\overset{a}{x}$ = 17,991 m^2, s.d. = 3,964), Chetro Ketl, Pueblo Bonito, Penasco Blanco, and Aztec Ruin, are, with the exception of

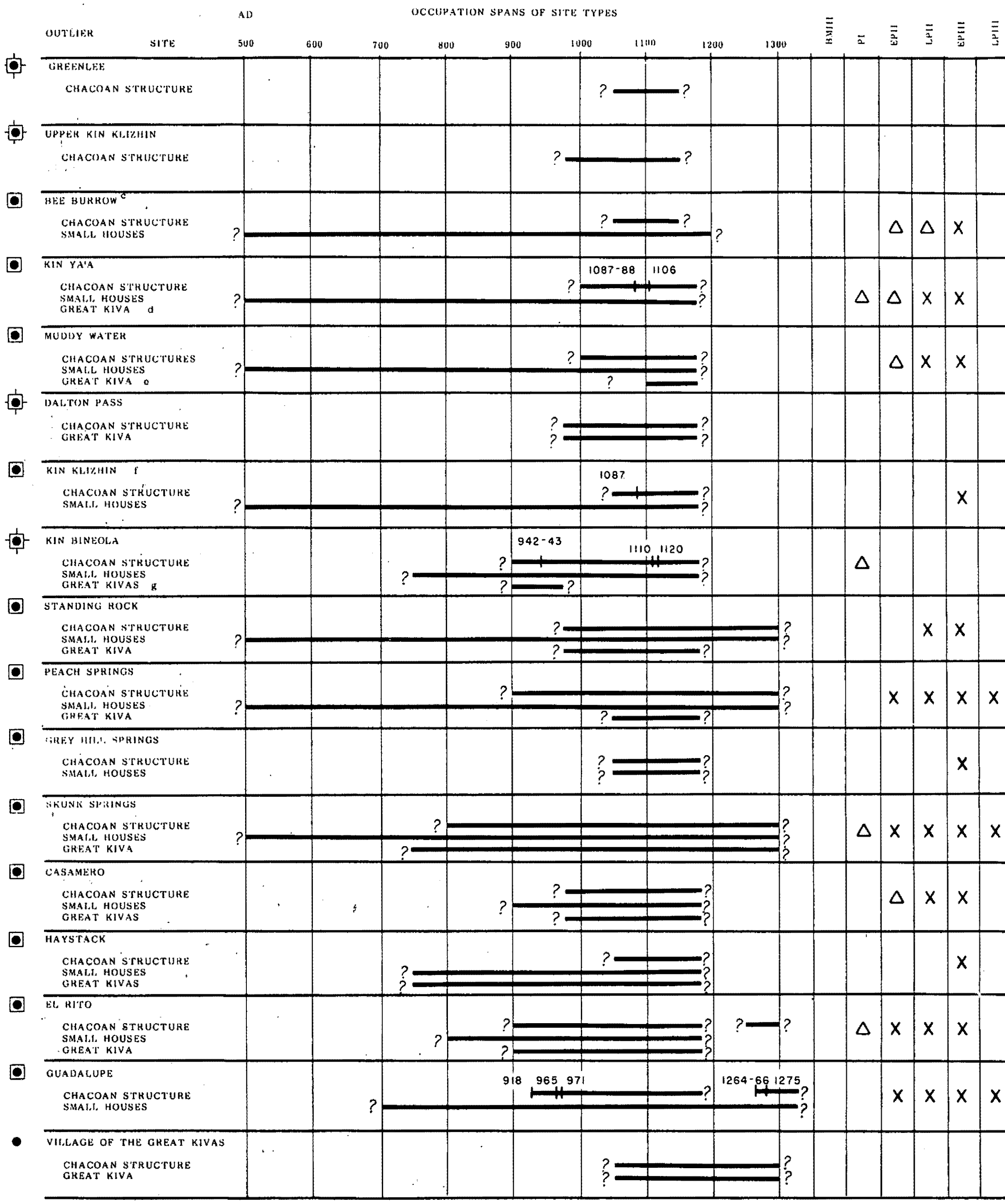


Table 1. Occupation intervals at outliers.

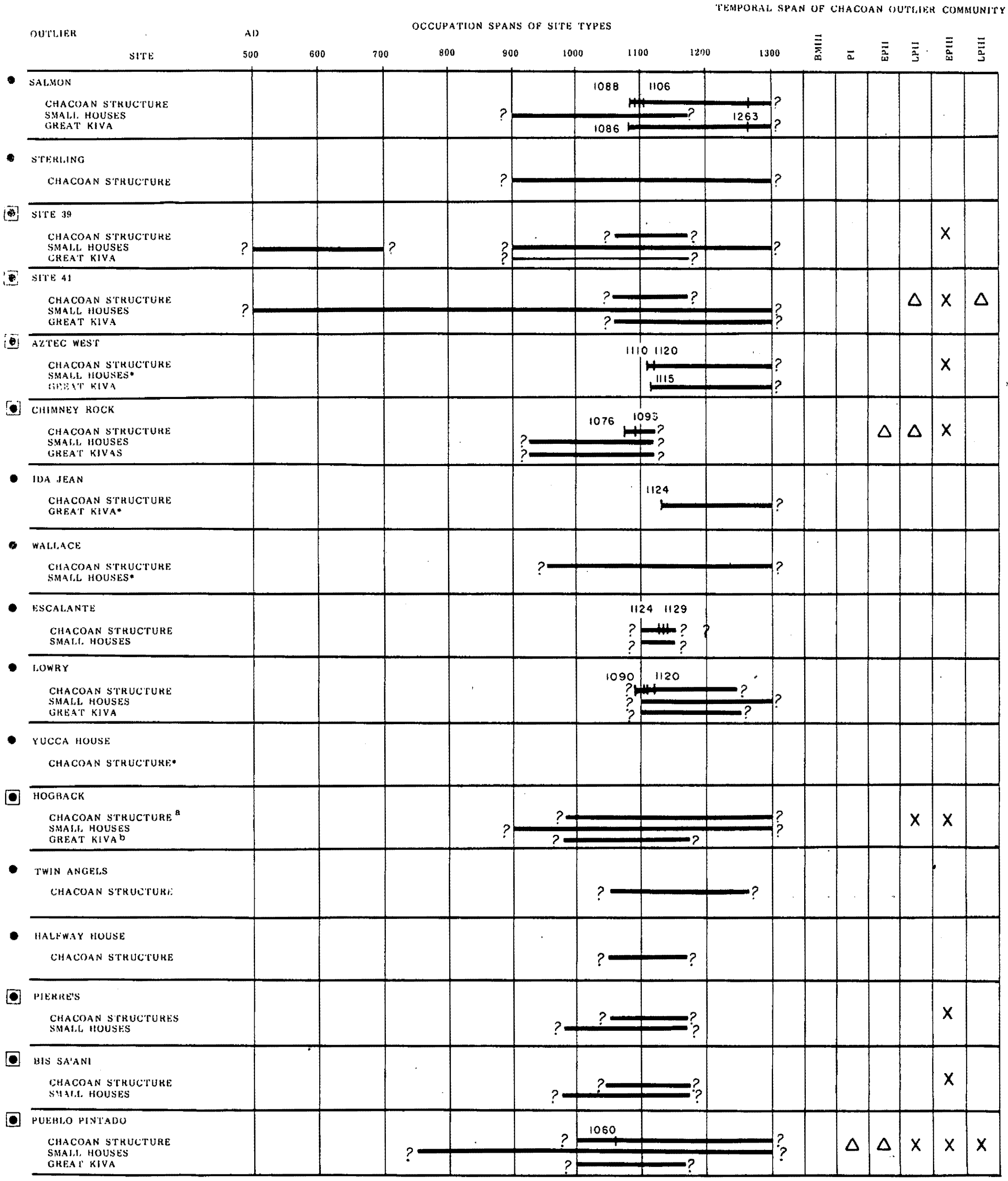


Table 1. (Continued).

TEMPORAL SPAN OF CHACOAN OUTLIER COMMUNITY

OUTLIER / SITE	AD 500	600	700	800	900	1000	1100	1200	1300	BMIII	PI	EPII	LPII	EPIII	LPIII
ALLANTOWN															
CHACOAN STRUCTURE						? ——— ?									
SMALL HOUSE					? ———	——— ?									
GREAT KIVA						? ——— ?									
HOUCK															
CHACOAN STRUCTURE							? ———	——— ?							

OCCUPATION SPANS OF SITE TYPES

? Occupation span estimated on basis of site ceramics. The EP III cutoff date of 1175 has been followed from Hayes (1981). Where ceramics of a time period are present in frequency adequate to indicate occupation, occupation throughout the duration of the period is assumed, unless excavation data, ceramic analyses, or dates limit or allow more specific placement.

1 Vertical bars indicate clusters of individual tree-ring dates suggesting major or probable construction. Earliest and latest construction dates are shown regardless of construction magnitude.

• Occupation spans of sites not known.

a - Examination of ceramics at Hogback indicates the presence of both EPIII and LPIII types. The late ceramics are apparently not reflected in Wiseman's or Marshall et al's (1979) samples for which Marshall has assigned a termination date of 1050.

b - Although white wares tabulated by Marshall et al. (1979) suggest LPII occupation, the high percentage of indented corrugated recorded by Marshall suggests continued occupation into EPIII.

c - Although the Bee Burrow Chacoan structure does appear to have an associated community, all BMIII-PI sites, and the majority of the EPII-EPIII community sites, occur between 1.6-2.4 km (1-1.5 miles) from the Bee Burrow structure.

d - Occupational periods of this great kiva (29Mc117) are uncertain. Hayes believes it was intruded into a PI-PII house mound. Exposed masonry in the kiva appears to be relatively late (1000s).

e - Occupation span impossible to determine because of lack of associated ceramic material (Marshall et al 1979). Possible ca. 1050.

f - BMIII-PII sites in the Kin Klizhin area are 1.6-2.4 km from the Chacoan structure and are equidistant from the Padilla Wash community. Their association with either community is as such arguable.

g - Refuse near both great kivas (Marshall et al. 1979) suggests EPII use, although it is not certain that the refuse accurately delimits the use span of either structure.

X Chacoan structure and associated community present during indicated period.

△ Community (without Chacoan structure) present during indicated period.

● Outlying Chacoan structure

▣ Outlying Chacoan structure and associated community.

⊕ Outlying Chacoan structure and probable associated community.

Table 1. (Continued).

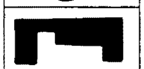
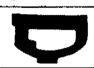
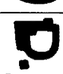
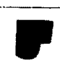
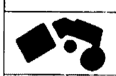
Chacoan Structure	Est. Floor Area (m^2)	Shape	Est. Mound Height (m)	Est. No. of Stories	Est. No. of Rooms	Est. No. of Kivas	Est. No. of Great Kivas [1]
Large							
Chetro Ketl	23,395		9.0*	4	580	16	2
Pueblo Bonito	18,530		10.0*	4	695	33	3
Aztec	15,030		8-9*	3	405	28	1
Penasco Blanco	15,010		4.6	3	215	7	4
Mean	17,991						
Std. Dev.	3,964						
Medium							
Pueblo del Arroyo	8,990		5.3+	4	290	15	1?
Una Vida	8,750		5.8*	3	160	6	2
Salmon	8,320		4.5-5.0	2-3	175	1	1
Pueblo Alto	8,260		3.5	1	130	15	-
Kin Bineola	8,225		5.0-6.0	3	230	10	1?
Hungo Pavi	8,025		6.1*	3	150	1	1
Pueblo Pintado	5,935		6.0-7.0	3	135	9	1?
Mean	8,072						
Std. Dev.	999						
Small							
Tsin Kletsin	3,552		3.3	3[a]	115	4	-
Allantown	3,460		4.5-5.0	3	100	5	1
Site 41	2,875		3.0-4.0	2	75	3	1
Kin Kletso	2,640		6.1*	3	135	5	-
Wijiji	2,535		4.8	3	190	2	-
Chimney Rock	2,535		4.0	2	55	2	-
Kin Klizhin	2,395		3.0-4.0	2[b]	18	3	-
Haystack	2,055		3.0-3.5	2	26	4	1

Table 2. Chacoan structure size and related attributes by size groups.

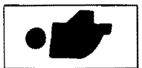
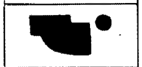
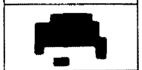
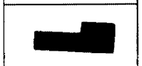
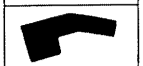
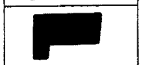
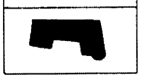
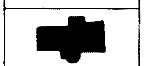
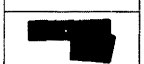
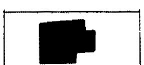
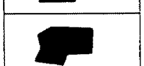
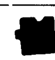
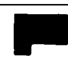
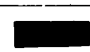
Chacoan Structure	Est. Floor Area (m^2)	Shape	Est. Mound Height (m)	Est. No. of Stories	Est. No. of Rooms	Est. No. of Kivas	Est. No. of Great Kivas[1]
Skunk Springs	1,935		2.5-3.0	2	45	3	1
Peach Springs	1,880		4.0	2	30	1	1
Kin Ya'a	1,845		3.0-4.0	2[c]	44	3	-
Sterling	1,685		?	1?	25	1	-
Casa Chiquita	1,460		3.9	3	80	2	-
Guadalupe	1,400		4.0-5.0	1?	25	3	-
Muddy Water Hurley Ruin	1,205		3.5	2	25	2?	-
Wallace	1,080		3.0-4.0	2	73	5	-
Bis sa'ani	1,040		3.0	2	37	5	-
Lowry Ruin	870		3.0-4.0	2	34	3	1
Dalton Pass	825		3.0	2	20	3	1
El Rito	795		3.0	3	55	4	1
Site 39	730		2.6	2	40	2	-
Ida Jean	695		2.0-2.5	2	55	2	1
New Alto	645		2.5	2	51	1	-
Casamero	635		2.5-3.0	2	26	2	1
Standing Rock	630		3.0-3.5	2	35	?	-
Village of the Great Kivas	590		2.5-3.0	1	18	2	1
Muddy Water Site 1	575		2.7	2	22	1	-
Pierre's Site 6	505		2.5-3.0	2	18	2	-
Upper Kin Klizhin	470		2.5-3.0	2	25	1	-

Table 2. (Continued).

Chacoan Structure	Est. Floor Area (m²)	Shape	Est. Mound Height (m)	Est. No. of Stories	Est. No. of Rooms	Est. No. of Kivas	Est. No. of Great Kivas[1]
Twin Angels	470		2.5	1	17	2	-
Escalante	455		2.5-3.0	1	25	1	-
Bee Burrow	450		3.0	1	11	2	-
Muddy Water Site 33	380		1.7	1	7	2	-
Pierre's House B	315		3.0	2	13	1	-
Pierre's House A	255		2.0	1	15	3	-
Greenlee Ruin	255		2.0	1	15	1	-
Grey Hill Springs	215		1.5	1	1	1	-
Hogback Ruin	205		2.5	1	10	1	-
Houck Ruin	200		1.8	1	9	2	-
Halfway House	145		2.0	1	12	?	-
Mean	1172						
Std. Dev.	955						

* - Indicates approximate height of standing masonry.
1 - Includes great kivas which are structurally part of the Chacoan structure or separate, but within 100 m.
a - Hayes (1981) suggests three stories for a few rooms; Lekson et al. (1982) argue for two stories only.
b - Three-story tower kiva
c - Five-story tower kiva

Table 2. (Continued).

the latter, all in Chaco Canyon. Seven medium-size sites ($\bar{x}$ = 8,072 m^2, s.d. = 999), Pueblo del Arroyo, Una Vida, Pueblo Alto, Hungo Pavi, Kin Bineola, Pueblo Pintado, and Salmon, are also in or near Chaco Canyon (with the exception of Salmon). The largest Chacoan structure in the numerous, small-size grouping (n = 41, $\bar{x}$ = 1,172 m^2, s.d. = 955) is less than half the size of the smallest medium-size site (Table 2). Unlike the medium-size sites, which occur primarily in or around Chaco Canyon, this third-order rank of sites is spatially very dispersed. Although small Chacoan structures occur in Chaco Canyon, the majority are outliers. Multiple stories, enclosed plazas, and great kivas occur most consistently and, in the case of great kivas, in greatest numbers at large- and medium-size sites. These features become progressively rarer as size decreases.

On the basis of these characteristics, corresponding differences in the social position and function of the sites are postulated. The great size of the two largest sites, Chetro Ketl and Pueblo Bonito, and their centralized positions both with respect to settlement in Chaco Canyon and to the convergence point of the outlying road system (the trajectories of incoming road segments suggest a convergence in the Pueblo Bonito-Chetro Ketl-Casa Rinconada area) imply that these sites occupied positions at the apex of power and importance in the Chacoan system and in some undefined fashion coordinated or controlled interaction between the canyon sites and outlying communities. A number of the other large- and medium-size sites, such as Penasco Blanco and Pueblo Alto, are located at natural entry corridors to Chaco Canyon in direct association with major incoming roads. The smaller size, less centralized location, and single road association of these sites identify them as second-order sites, which may have directly controlled a single road system and its attendant outlying communities. At the third, and lowest level of the hierarchy, are the small-size, widely dispersed, outlying Chacoan structures with their attendant communities. The road association and relatively large size of these structures within the outlying community identifies them as local centers.

While it seems clear that Chacoan structures on all levels were important structures, probably with some combination of economic, political and ceremonial functions, their exact purpose and range of use remain unclear. Some were almost certainly partially permanent residences (Judd 1964; Windes 1982), but serious questions remain concerning whether they were community meeting or ceremonial centers as implied by Marshall and others (1979), storage repositories (Lekson and Judge 1978), elite residences or some combination thereof (Lekson this volume, Schelberg this volume). Given the hierarchical nature and complexity of the settlement system, it is proposed that at least a small elite population had evolved by the late eleventh century and was in residence at the large- and medium-size sites. Limited evidence for high status burials at Pueblo Bonito (see Reyman 1978; Akins and Schelberg this volume) lends some credence to the argument.

The presence of large (Aztec) and medium (Salmon) sized Chacoan structures on the San Juan and Animas Rivers, 70-80 km north of Chaco Canyon, appears anomalous with respect to the foregoing interpretation and raises important additional questions concerning the relationship of these sites to those of comparable size in Chaco. Possibly Aztec and Salmon were rivalling the Chaco Canyon centers in importance and influence by the early 1100s and, if so, may have been contributing elements in the downfall of Chaco.

Regional Environmental Diversity

Environmental differences in the locations of outliers in the San Juan Basin are substantial. Low effective environmental diversity, relatively low mean annual rainfall, and poor highly saline soils at many central basin locales contrast with relatively high effective environmental diversity, slightly higher mean annual rainfall, superior water quality, and better agricultural soils at many basin periphery locations. This regional variability is amplified on another dimension by substantial and relatively unpredictable annual precipitation (Schelberg 1982). In combination, these factors create a picture of differential natural resource distribution and availability throughout the region, and indicate the potential for differences in crop productivity. This variability is critical because it establishes a need for resource exchange as a means of buffering climatic unpredictability and resource deficiencies and thereby provides a possible, but partial, explanation for why the Chacoan system evolved (Judge 1979). The archaeological record indicates some lithic (Cameron this volume) and substantial ceramic exchange (Toll this volume) during this period, but has not yet provided substantive evidence of the exchange of a wider range of subsistence related resources or of the storage and redistribution of food crops. A great deal of further evidence from a large number of outliers and, perhaps, advances in methodology and technology of archaeological analyses may be required before this question can be resolved.

Ceramic And Lithic Exchange

Substantive evidence of the exchange of ceramic and lithic materials has resulted from NPS excavations in Chaco Canyon, as reported by Toll (this volume) and Cameron (this volume), and as indicated by the surface occurrence of nonlocal ceramics and lithics at many outliers (Powers and others 1983). Ceramic exchange includes trachyte and andesite/diorite tempered vessels from the Chuska Valley and San Juan River valleys. The major exotic lithic materials are Washington Pass chert, yellow-brown spotted chert, and obsidian from known source areas in the Chuska Mountains, Zuni Mountains, and Jemez Mountains (minor obsidian sources also include Grants Ridge and Red Hill), respectively.

The spatial distribution and frequencies of these materials allow limited reconstruction of exchange patterns, but the incomplete nature of present data renders all conclusions tentative. With the exception of obsidian, which appears to have a relatively ubiquitous but low frequency distribution, the other lithic and the ceramic materials have more limited, but higher frequency, distributions. These distributions include sites in the general vicinity of the source area, outlier communities and roads nearest the source, and Chaco Canyon. Although there are exceptions, in general as distance from the source areas increases there is a definite and noticeable fall-off in the frequency of these materials.

Trachyte-tempered ceramics and Washington Pass chert comprises very substantial percentages of the total surface and excavation samples at major Chaco Canyon Chacoan structures suggesting more than indirect and sporadic reciprocal exchange (Powers and others 1983). Instead, the quantities of material present are more indicative of continuous and higher volume trade. The relatively low frequencies of trachyte-tempered ceramics and Washington Pass chert at outliers on road systems removed from the source area tend to discredit the proposition that major Chaco Canyon sites functioned efficiently as redistribution centers for these goods. Instead the trade items appear for the most part to have been consumed in Chaco. It should be emphasized that a pattern of consumption of some goods in Chaco does not necessarily indicate that all exchange goods were so consumed.

Summary And Conclusions

In summary, the presence of numerous communities with an associated Chacoan structure, the road linkage of many of these communities, and a size hierarchy of Chacoan structures suggest the evolution of a complex cultural system within the San Juan Basin during the time span between the tenth and twelfth centuries. As the locus of road convergence and the majority of hierarchically preeminent sites, Chaco Canyon is identified as the regional center of the Chacoan system. Regional environmental diversity and the unpredictability of annual precipitation in the semiarid San Juan Basin suggest that the exchange of resources to provide locally unavailable or deficient items may in part have been a causal force in the evolution of the Chacoan system. However, exchange of a wide range of subsistence related goods cannot be either confirmed or discounted without additional major research.

Substantial quantities of intrusive ceramic and lithic materials are indicative of exchange between outliers and Chaco Canyon Chacoan structures, with the canyon being a major consumer of some items. If Chaco was relatively ineffective as a redistributor or did not function at all as a redistributive center to outlying communities, as present evidence suggests, it must be determined if alternate goods or services were provided to outlying communities. One possibility is that the major Chaco Canyon sites controlled distribution of materials not available within the range of San Juan Basin outliers. Such exchange goods might include turquoise, obsidian, shell, cotton, salt, and exotic Mexican imports. Otherwise, or additionally, Chaco may have provided organized seasonal labor forces to construct outlying Chacoan structures or great kivas as part of a concerted effort to indebt and form alliances with community groups throughout the San Juan Basin. Ceremonial and kin ties undoubtedly acted to further cement these connections. While it is not yet known what combination of causal elements initiated the development of such a regionally based system, it is probable that once it was underway, interaction of social, political, agricultural, ceremonial, and exchange aspects resulted in increasing change and complexity. The causes of the collapse of the system around A.D. 1150-1175 are similarly unknown. A number of factors, including possible overpopulation, resource depletion, a 50-year summer precipitation drought lasting from A.D. 1130-1180, and intercommunity strife and competition may have taken a cumulative toll.

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CHACOAN COMMUNITY STRUCTURE: BIS SA'ANI PUEBLO AND THE CHACO HALO *

David E. Doyel
Cory D. Breternitz
Michael P. Marshall

Abstract

While much fascinating and innovative research is currently being accomplished on the Chacoan regional system, this article points out an important topic that has been overlooked too long, that being the structure of the Chacoan communities and the implications of community structure in the regional interactive system. This contribution will be concerned with the Chacoan community structure, and will illustrate some research perspectives implemented in a recent study of Bis sa'ani, a late Bonito Phase community located near Chaco Canyon. An interpretive model, introduced here as the "Chaco Halo," is presented as a first-order attempt to model the various levels of interaction among the Chaco Canyon megacommunity and those communities located peripherally to the canyon zone.

Introduction

Much of the innovative research accomplished in the American Southwest within the past decade has focused upon aspects of the Chaco Anasazi regional system. Studies of the paleoenvironmental change, settlement patterns, social organization, architecture, ceramic production, raw material procurement, exchange, water control systems, subsistence, prehistoric roads, archaeoastronomy, Mesoamerican connections and many others have all been attempted, many with positive results. One of the most important recent developments in research trends has been the explicit recognition of a high degree of interaction among sites located both within and outside of Chaco Canyon; Chaco appears to have been a dynamic if somewhat fragile cultural expression that encompassed most of the San Juan Basin (Altschul 1978; Judge 1979). It was perhaps the discovery of hundreds of kilometers of prehistoric roads interconnecting more than 60 Chaco-related settlements that has hastened the acceptance of the Chaco as a highly interactive regional system (Obenauf 1980; Kincaid 1983).

One additional recent development, and one too long overlooked, is the study of Chacoan community structure. With the exception of several studies (Marshall and others 1979; Powers and others 1983), this important topic has not received sufficient attention. By communities, we are here referring to a group of spatially related but noncontiguous contemporary settlements of various types that were integrated on the local level into a functioning sociocultural entity. It has been common knowledge for at least the past several years that many of the so-called "outliers," "satellites," or whatever one chooses to call them, are not composed of one big site or several architectural units, but instead often contain many noncontiguous sites clustered within a defined boundary area or zone. These sites usually contain a variety of features including kivas, great kivas, great houses, room blocks, shrines, habitation units, field houses, field areas, and other specialized aspects or components. Continued research has indicated that, while sharing certain architectural similarities, these communities vary considerably in size, the range of features present, and perhaps function.

It should also be pointed out that the pattern of centralized community organization is a general characteristic of the eastern Anasazi province and is not exclusively a Chacoan phenomenon; the pattern has considerable time depth in the San Juan and Chuska, Red Mesa and southern Cibola regions. This form of community structure does contrast with the western Anasazi, such as the Kayenta and Virgin branches, where centralized public architecture is rare. The development of centralized public architecture in the eastern Anasazi provinces can be traced from the emergence of great

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kivas during the Basketmaker III period to the massive Bonito-style buildings, extensive roadways, and other facilities of the Bonito Phase. The so-called Chacoan outliers of the San Juan and Chuska regions probably represent centers maintained by local populations, which cannot necessarily be envisioned as being under the direct control of the Chaco Canyon center. These communities do, however, clearly reflect certain "Chacoan" characteristics and can therefore be regarded as Chaco-related.

For a community to be identified as Chaco-related, it should express several of the following attributes. A distinct constellation of sites aggregated into an area defined by either natural or cultural boundaries is characteristic. Public buildings in the form of one or more great kivas and a Bonito-style "great house" structure should be present. Additional features may include roadways or formal stairways terminating at the public buildings; shrines, earthworks, stone circles, reservoirs, and irrigation facilities may also be present.

An inventory of Bonito-style structures reveals several common architectural elements, among which are: massive core-veneer masonry constructions, massive masonry and timber construction that often exceeds the enclosed space, blocked-in surface, elevated or tower kivas, great kivas, multi-storied constructions, large rooms with high ceilings, symmetrical layouts indicative of extensive preplanning and several major building events, plaza enclosures, placement in elevated positions, and associated roadways and stairways terminating at the public building. There are clearly various schools of Bonito-style architecture in the San Juan, Chaco, Chuska, Red Mesa, and southern Cibola regions. All appear to have been involved in the use of the great kiva and the subsequent development of the great house; however, other more subtle structural specifics and arrangements seem to vary among these schools. The Bonito-style structures associated with Chacoan communities are considered to have functioned as community centers of public facilities for a variety of ceremonial and other activities (Marshall and Doyel 1981:56-61).

This paper will be concerned with two aspects of Chacoan community structure. One, what is the internal structure of these communities; how are they organized on a local level? And two, what was the role or roles of these individual communities within the regional system? A recent study undertaken by the authors will be summarized to illustrate some suggested research directions and interpretive models for the study of Chacoan community structure.

Community Studies

Most studies of Chacoan communities located outside of Chaco Canyon can be described as site specific in nature, and often focused upon the massive architectural features associated with the community. Earlier reports were more descriptive and historical in nature, such as Roberts' (1931) work at Allentown and the Village of the Great Kivas (1932) and the work by Morris at the Aztec Ruin (1919, 1928). More recent investigations reflect the general trend towards cultural interpretation based upon detailed analysis of artifactual, architectural, economic, settlement system reconstruction and other studies (Pippen 1979; Irwin-Williams and Shelly 1980). Recent analysis by Judge and the Chaco Center focusing upon the Chaco Canyon "mega-community" seems to have a model of interacting communuities embedded in the interpretation of social and economic evaluation of the Chacoan system (Judge 1979; Judge and others 1981). Several other important studies have been accomplished that focus on community organization. These studies have documented known site areas located peripherally to Chaco Canyon and have identified many large sites located within the San Juan Basin that are apparently connected with the Chacoan system (Marshall and others 1979; Powers and others 1983). Both of these studies identify and describe many ruins and clusters of ruins from a community perspective, although much of the emphasis was necessarily placed upon the massive architectural features commonly associated with these communities.

Subsequent work has been done to further characterize the nature and composition of Chacoan communities located outside the canyon proper (Marshall and Doyel 1981; Breternitz and others 1982). Two basic types of communities have been identified to date and are known as "ancestral" and "scion." Ancestral communities have significant time depth, perhaps reaching back into the Basketmaker III period. Such sites often possess a wide range and great quantitiy of features and are usually located in favorable environments where arable land and water are available. In contrast, scion communities appear late in the Chaco sequence, have limited time depth (usually late Bonito Phase), are often smaller in size, lack features typical of ancestral communities such as great kivas, and are often located in marginal environment zones. Scion communities may have developed as a result of population growth, immigration, factionalism within ancestral communities, or as satellite communities to exploit locally available resources or markets.

Both ancestral and scion communities contain a variety of features within their boundaries. Both contain nuclear areas where the highest site density and the majority of settlements are located. This nuclear area also contains the associated massive Bonito-style public buildings such as great kivas and great houses. The density and arrangement of the numerous and usually relatively small habitation sites within the community can vary considerably. In certain instances sites appear to be scattered about on the landscape (e.g., Bis sa'ani, Pierre's Site) whereas in other cases sites are placed in orderly arrangements that approach a street-like quality (e.g., Muddy Water, Standing Rock, Peach Springs, Skunk Springs).

Communities also include other spatial-functional aspects that can be recognized within each configuration. Subnuclear constellations can be recognized and may consist of a small cluster or clusters of habitation sites that exist beyond the central or nuclear area but were apparently still allied to the nuclear community and its public and ceremonial facilities. Agricultural zones and other special function sites, such as hearths, chipping stations, rock art localities, and shrines comprise other aspects of the typical Chacoan community. The unsettled regions located beyond the confines of the community area are termed settlement voids. Such areas were often used as raw material procurement areas, hunting and gathering localities, trail and road avenues, temporary campsites, and on occasion as shrines.

Continued inspection of the various communities located outside of Chaco Canyon prompted more questions about their internal structure and function, as well as how such communities were articulated into the regional system of which they appear to have been integral partners. Marshall and others (1979:337) suggest an initial breakdown between what they called "transportation-related" and "production-related" communities. Transportation-related communities, many of which appeared to be of the scion type, were small in size, lacked great kivas, and were located along prehistoric roads in areas of marginal agricultural productivity. Production-related sites were located near especially favorable agricultural areas and theoretically could have produced surplus quantities of food and other items for exchange. While this transportation-production dichotomy is known to oversimplify a rather complex settlement pattern, it did nonetheless introduce the idea of specialization among the various communities. The spatial distribution and known source areas for other materials found in Chacoan sites, such as construction timber, shell, pottery, and stone also suggest that community specialization could have been an aspect of the Chacoan system.

A recent data recovery program located near Chaco Canyon provided the opportunity for the authors to investigate a small Chacoan scion community situated along the Escavada Wash. Two of the general research qustions asked were "What was the internal structure of this community, and how did this community articulate with other such communities both within and outside of the canyon?" Before addressing these general questions, a brief introduction to the Bis sa'ani community is presented.

The Bis sa'ani Community Study

The Bis sa'ani community is located on the wide and nearly level flood-plain of the Escavada Wash approximately 15 km north of Chaco Canyon. The core of the community is situated one to two kilometers south and west of Bis sa'ani Pueblo between the Excavada on the north and an exposed badland escarpment on the south. This highly dissected and colorful badland escarpment, 20 to 30 m high, is devoid of vegetation and forms the divide between the Gallo and Escavada drainages. A number of small habitation sites are located along this escarpment, either slightly raised above the flood-plain or situated on isolated pinnacles (Figure 1). The exposed sediments consist of alluvial deposits and isolated

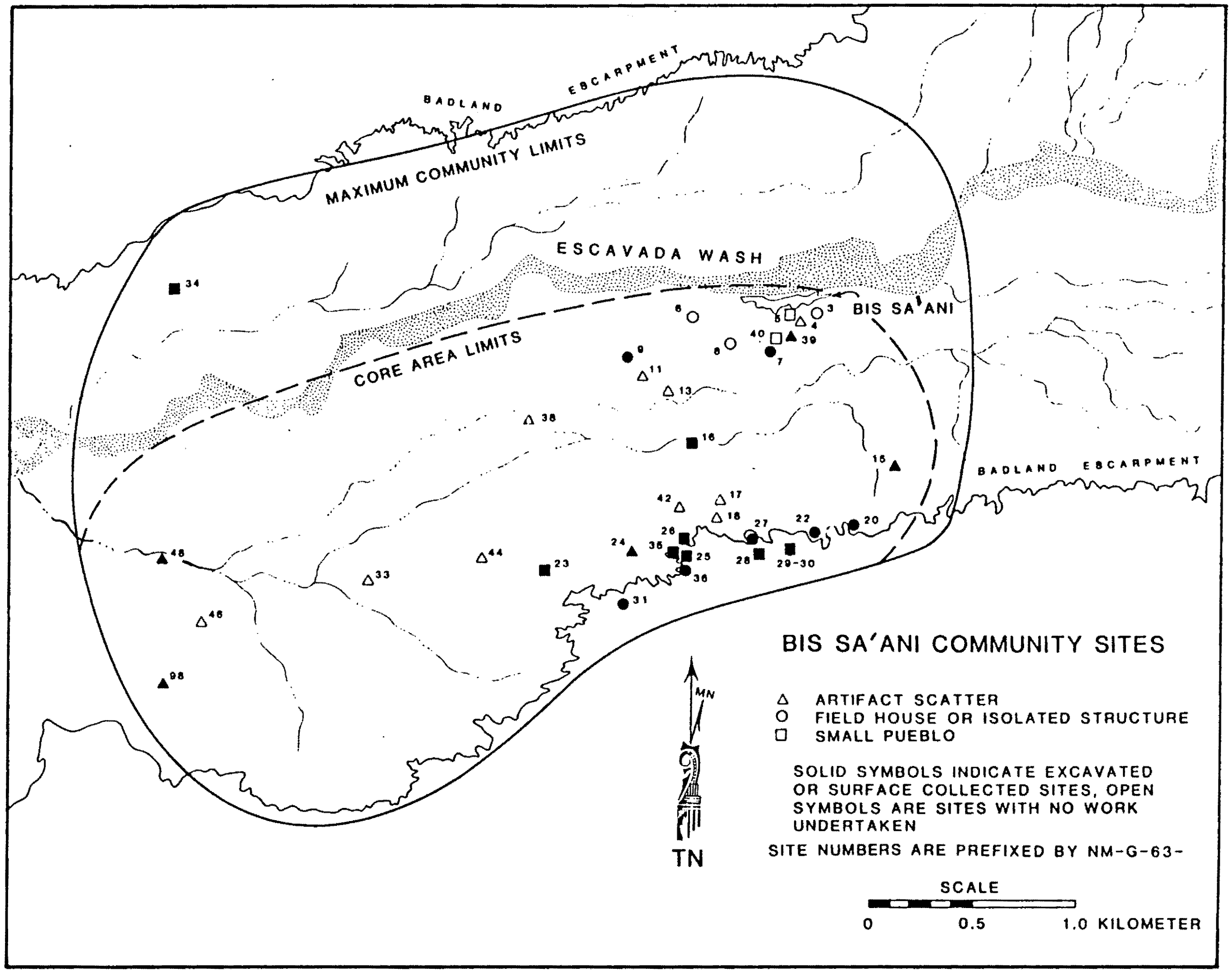

Figure 1. Map of the Bis sa'ani community area showing the distribution of site types. Site designation follows the Navajo Tribal Museum system.

erosional remnants deriving from the Cretaceous shale and coal beds of the Kirtland-Fruitland Formation. The vegetation consists of sparse covering of saltbush, greasewood, wolfberry, Indian rice grass and dropseed.

Bis sa'ani Pueblo, a Bonito-style great house structure, is the most visible feature; however, the core of the community is contained in 35 small pueblos and isolated structures situated within a 10-km^2 area located to the south and west of this elevated Chacoan structure. As one of the first analyses of an entire Chacoan community, the Bis sa'ani study attempted to investigate basic questions of origin, growth, and development. It was oriented primarily toward the study of community structure, focusing particularly on the local system and secondly on the relationship between the local system and the Chacoan regional system.

The contemporaneity of the sites in the Bis sa'ani community has been demonstrated through the use of ceramic cross-dating, archaeomagnetic and tree-ring dating techniques. These dating methods indicate that the construction and use of the buildings at Bis sa'ani Pueblo and those at the surrounding habitation sites were contemporaneous. Based on 18 archaeomagnetic dates and 16 tree-ring dates, the community has been dated to a 50-year period between A.D. 1100 and 1150. The success of these absolute dating methods is strengthened by a well-dated ceramic assemblage (Franklin 1982), making Bis sa'ani the only well-dated community in the San Juan Basin.

A preexisting hierarchy of site size, form, and function was observable across the area defined as the community. It is dominated by the imposing mass of Bis sa'ani Pueblo, situated on the summit of a steep-sided narrow clay ridge some 20 m above the Escavada floodplain. The 35 small sites identified as the Bis sa'ani community represent three general types including 15 limited-use sites (sherd and lithic scatters); 10 isolated structures, both domiciliary field houses and isolated kivas. As part of the data recovery program, five limited use sites, seven isolated structures, and eight of the small pueblos were excavated and a variety of proveniences at Bis sa'ani Pueblo were sampled (Breternitz and others 1982).

The limited-use sites are localized surface scatters consisting of chipped and ground stone artifacts and a sparse scatter of ceramics. These nonarchitectural sites probably represent areas of agricultural-related and/or resource procurement and processing activities that were repeatedly utilized. Ten isolated structures were identified, several of which exhibited domiciliary features such as fire pits, storage pits, and grinding areas. The five kivas identified in the Bis sa'ani community occur both as isolated structures (three instances) and in direct association with two of the small pueblos. The other isolated structures resemble field houses or storage structures at the edges of fields. The 10 small pueblos have many of the attributes of small unit-type pueblos common throughout the Colorado Plateau and include domiciliary rooms with firepits, storage pits, grinding areas, wall niches, doorways (both sealed and open), and storage structures, which often occur as pairs of rooms attached to the living rooms (Figure 2). Nearly all of the small pueblos have an associated extramural work area located either to the south or east of the main room block. Two of the sites have separate walk-in storage rooms with stepped entrances.

The architectural features at Bis sa'ani Pueblo, both ceremonial and domestic, represent classic Bonito-style architecture as characterized by core-veneer masonry, blocked-in "Chacoan" style kivas with intentionally filled interstitial spaces, a high kiva-to-room ratio, and a structural mass that exceeds the roofed floor space. In addition to these, Bis sa'ani possesses a number of unique features including four stairways; adobe architecture; large, massive wall foundation platforms; narrow subdivided platform rooms north of each kiva; color masonry banding; a masonry box with a shaped stone lid; and a semicircular jacal structure. These attributes and the elevated position of the pueblo combine to give Bis sa'ani a very massive and impressive appearance (Figure 3).

A majority of the roofed area at Bis sa'ani Pueblo was devoted to five large kivas; however, the four buildings comprising the eastern complex had a number of domestic structures and storage rooms, including a room with 12 grinding bins. Casa Quemada, the central building flanked by the massive kiva complexes of Casa Hormiga, Rabbit House, and South House, is a 20-room domestic complex constructed of puddled-coursed adobe

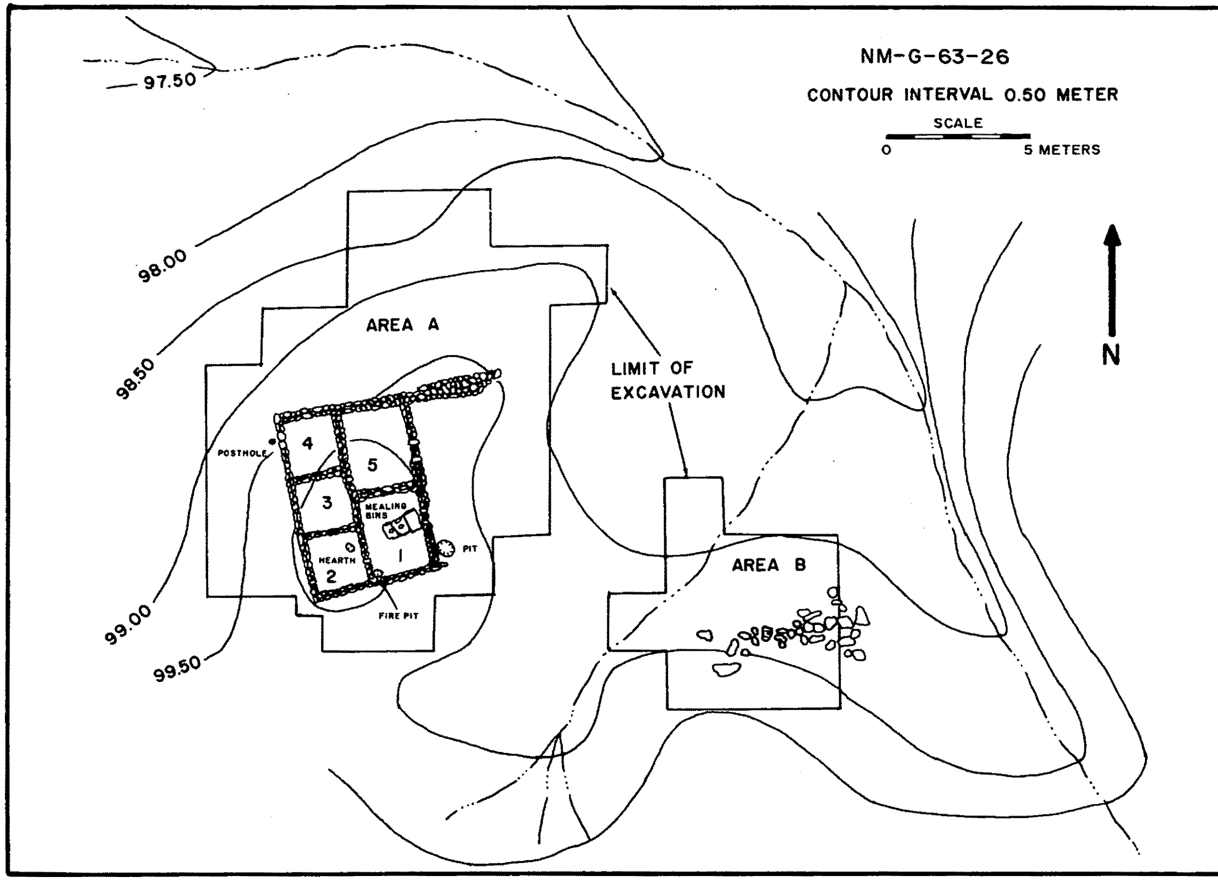

Figure 2. Site NM-G-63-26, a typical small pueblo habitation site in the Bis sa'ani community.

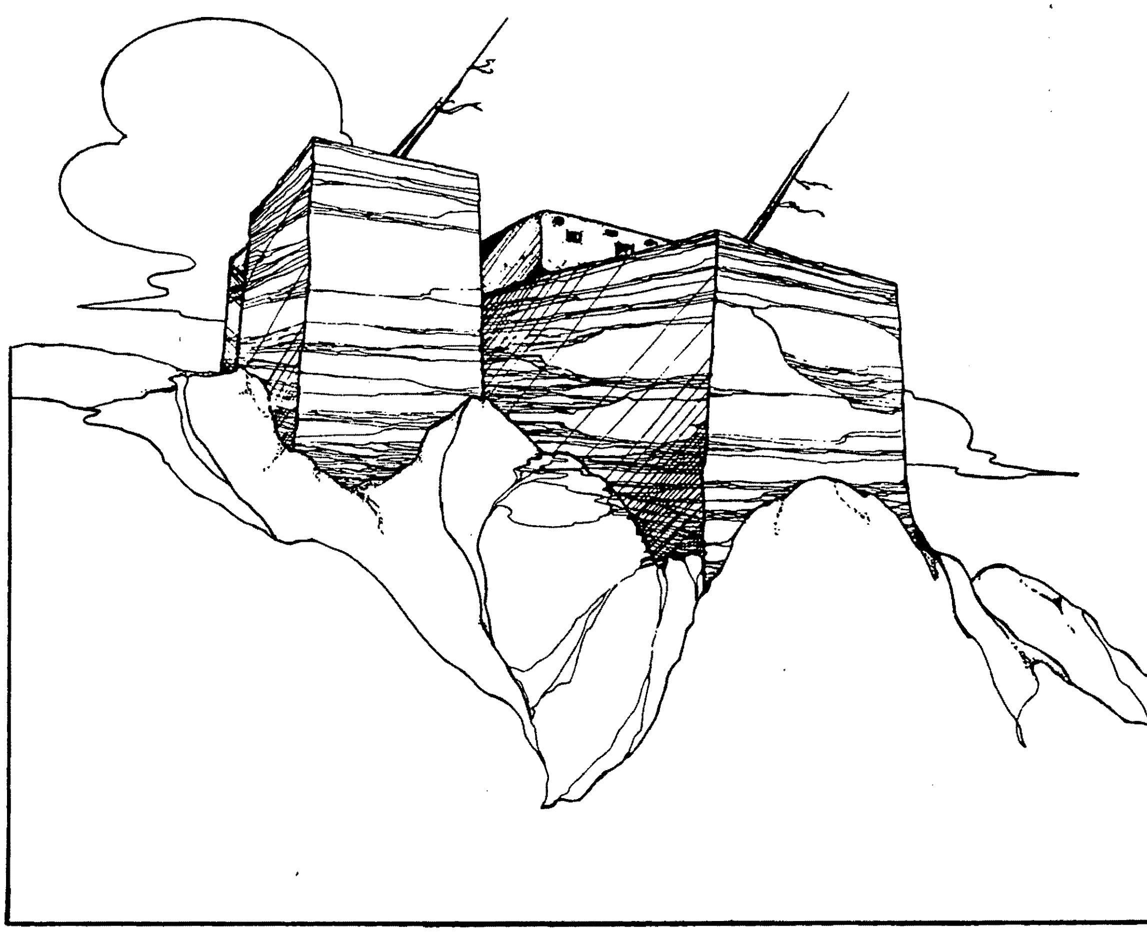

Figure 3. Artist's reconstruction of Bis sa'ani Pueblo, ca. A.D. 1150. Casa Hormiga, Casa Quemada, and South House kiva (l. to r.); vertical height of retaining walls approximately 8 m.

(Figures 4 and 5). West House, the fifth main building or structure at Bis sa'ani, is located approximately 100 m west of the main eastern house complex and consists of a large kiva and 10 associated masonry rooms, some of which appear to have served domestic functions.

The distribution of site types and features across the Bis sa'ani community area suggests that the small pueblos functioned as permanent habitations. Each accommodated one or more family units, which would have in turn utilized the various limited-activity sites and isolated structures found throughout the community zone. There are five kivas at Bis sa'ani Pueblo and five kivas in the small sites; two were incorporated into small pueblos and three were isolated kivas. The three isolated kivas are interpreted as serving a number of small pueblos and isolated structures, perhaps acting as the catalyst for a cooperative group operating above the family level, referred to herein as a neighborhood. Three neighborhoods have been tentatively defined for the Bis sa'ani community, each consisting of a collection of permanent small pueblo habitations, several isolated field house structures, and limited-use sites. Perhaps each of the five kivas and their respective site/neighborhood groupings were associated with a specific kiva at Bis sa'ani Pueblo. These community kiva groups may have congregated at their respective kivas at Bis sa'ani Pueblo for ceremonial and social gatherings during selected times of the year. It is also possible that kiva groups in the community traded off maintenance and residence duties at Bis sa'ani Pueblo in accordance with the seasonal economic and ceremonial cycles.

There is a noticeable dichotomy in dimension and content between the Bonito-style architecture at Bis sa'ani and the more mundane architecture of the community sites. We have interpreted this dichotomy as the result of different functions and uses of space, the use of Bis sa'ani Pueblo having been largely public and cooperative while that of the community sites was domestic and domiciliary. The residential units in Casa Quemada in association with a number of large kivas could suggest a resident elite, but the construction and maintenance of the monumental structures at Bis sa'ani probably represent the various social groups in the community. As noted, each of the five kivas in the community may have its counterpart at Bis sa'ani Pueblo.

The artifactual remains recovered from Bis sa'ani Pueblo generally reflect the domestic culinary activities typical of the community sites. The milling facilities at Bis sa'ani and the community sites are also very similar, both exhibiting communal as well as individual grinding areas. Bis sa'ani Pueblo does differ from the small sites in the presence of certain exotic materials. Bis sa'ani has slightly higher percentages of intrusive ceramic and lithic material types, and the faunal assemblage is more diverse with several rare or exotic types represented. Perhaps the most interesting, and certainly the most unusual, artifacts encountered at Bis sa'ani constitute a collection of 31 apparent "cult" objects found sealed in a pit below a room floor in Casa Quemada. The collection includes four phallus-like objects, several ground sandstone tablets and disks, a large siderite concretion, and several cores and flakes (Figure 6). These cult objects are unusual, even for a Bonito-style great house. Several other exotic items, most in the form of ornaments, were also present and include stone palettas, a copper bell, West Coast marine shell, a jet ring fragment and turquoise. None of these items, except for several pieces of shell, were present at the small sites.

Bis sa'ani Pueblo undoubtedly held some special significance in the social and secular organization of the community. It required a cooperative effort to construct and presumably to administer, and may have served some limited redistribution or warehousing function within the Bis sa'ani community. The structure of the surrounding community seems to have been one of mutual interdependence for subsistence, social and secular amenities. The short-lived community probably represents the colonization of an area that until the late Bonito Phase was regarded as unsuitable for agriculture. The combination of population growth, extensive overexploitation of the environment, and the continuing evolution of the Chacoan regional system may have all contributed to a cultural, economic, and social response that manifested itself as the "late Bonito Phase," and that is typified by the Bis sa'ani community.

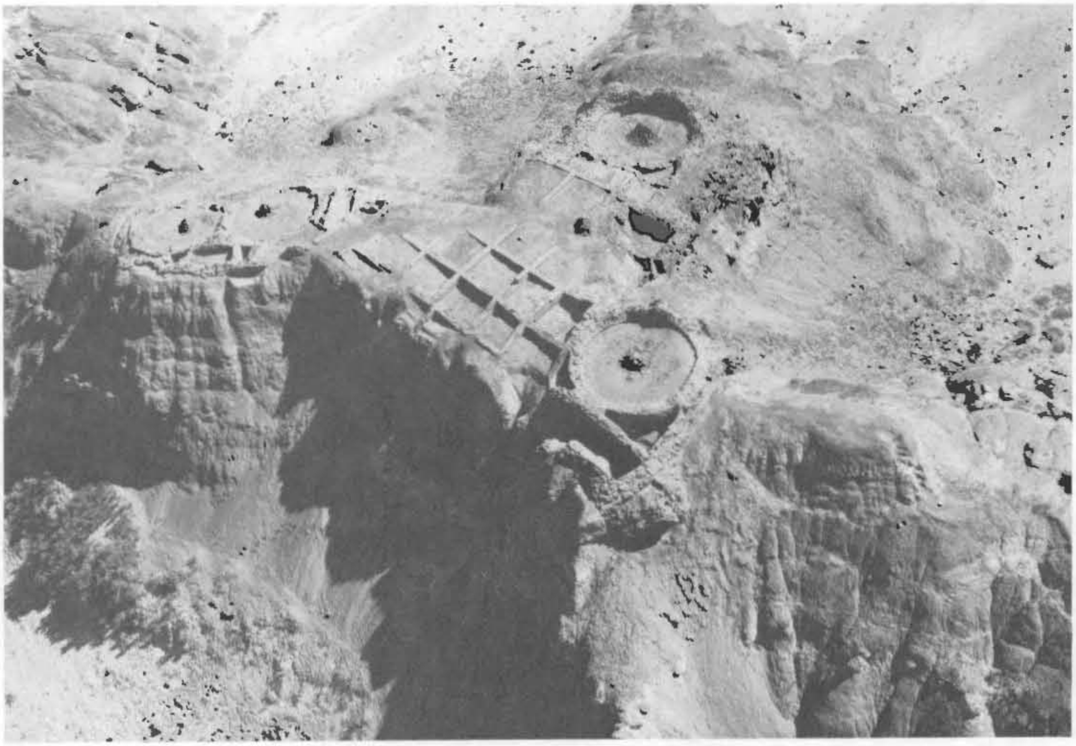

Figure 4. Aerial view of the eastern complex at Bis sa'ani Pueblo looking south, showing the central puddled-coursed adobe structure of Casa Quemada flanked by three masonry kiva complexes of Casa Hormiga (front), Rabbit House (left), and South House (rear).

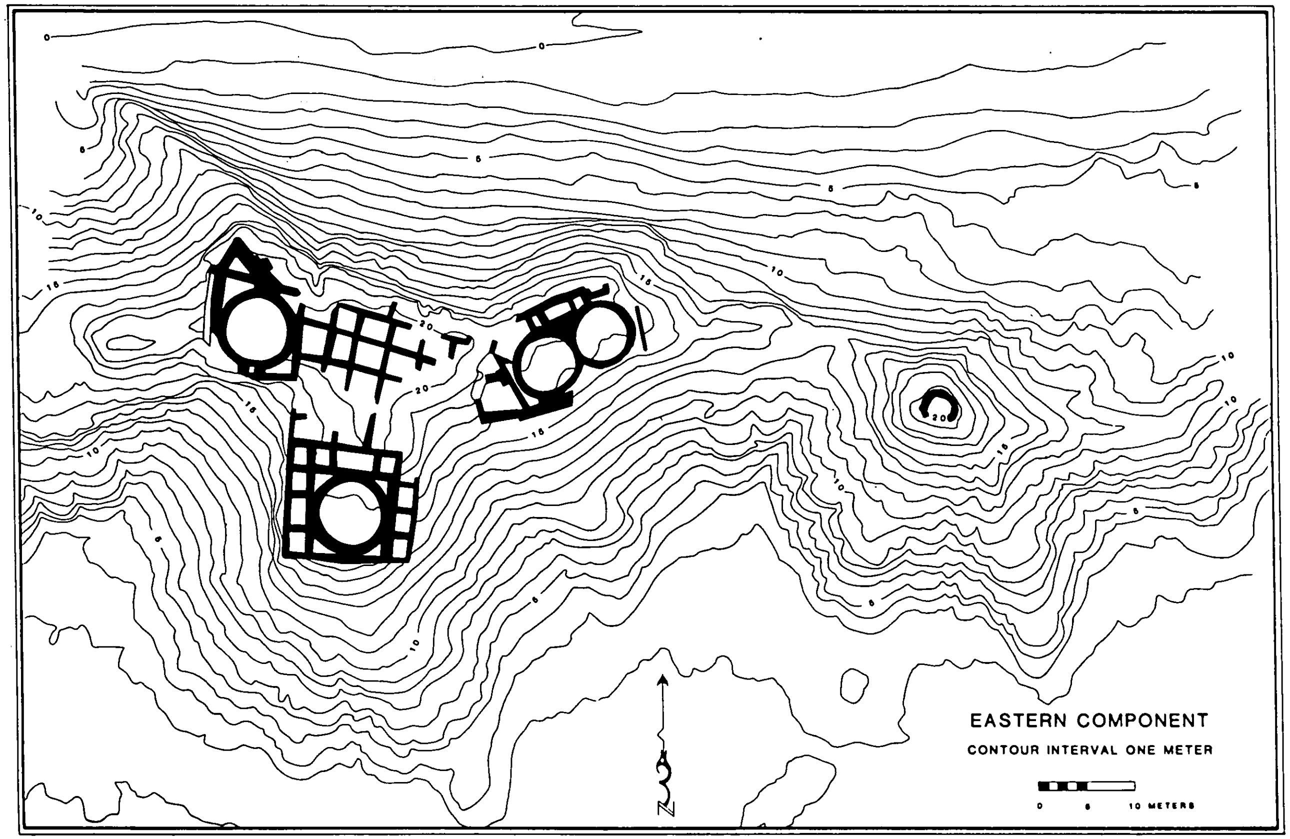

Figure 5. Topographic plan view of the eastern complex at Bis sa'ani Pueblo; South House kiva is in the foreground (see Figure 4).

Figure 6. View of "cult objects" as they were found sealed in a pit below a room floor in Casa Quemada. The assemblage included four phallus-shaped stones, a large siderite concretion, a piece of shaped hemetite, several shaped sandstone tablets and discs, and a number of small chipped stone items.

The Function Of Bis sa'ani Community

One aspect of the study was oriented toward the possibility that Bis sa'ani and perhaps other Chacoan communities were somehow specialized sites that could have been established to help support the populations and massive ceremonial centers located within Chaco Canyon. Since Bis sa'ani is suspected of lying along a road, perhaps the community was somehow related to transporation, possibly as a way-station or a point of redistribution. Alternatively, could the marginal location of Bis sa'ani have created food shortages that would have required inputs from other communities in order to insure survival?

To answer the question of specialized subsistence production, a study was undertaken to address the relationship between production and carrying capacity of the community zone. A detailed analysis of the physical environment of the area was undertaken. Ethnographic and informant sources were consulted for purposes of identifying the range of farming practices known to have been used in the area (Cully and others 1982). By way of summary, it was learned that approximately 150 to 190 hectares of land were locally available for farming. Ethnographic data indicate that this amount of land can support between 123 and 153 people, including some provision for storage. The archaeological site data were summarized and subjected to various formulae, which resulted in estimates of local population ranging from 70 to 127 people. An average estimate of the population within the Bis sa'ani community would be around 100 people. These figures alone tell us that Bis sa'ani was not a major Chacoan community; the small size apparently was correlated with the carrying capacity of the local environment.

The above data do permit further characterization of the structure and function of the Bis sa'ani community. The analysis undertaken suggests that the local environment was sufficiently productive to support the population without benefit of outside assistance. It should be remembered that these estimates are based upon the projected production of local agriculture and do not take into account hunting or gathering or the possibility of fields located some distance from the community area. While the local population could have provided for itself, the analysis also suggests that little if any surplus could have been produced for trade or exchange either into neaby Chaco Canyon or to other regional communities. A variable that could affect this scenario is the possible double counting of the population of Bis sa'ani Pueblo. If, in fact, only a small maintenance population inhabited the main pueblo on a year-round basis, then perhaps our population estimate for the community as a whole may be overinflated approximately 25 percent. This difference might suggest the possibility of some surplus production but still clearly on a low order of magnitude.

Our quantitative approximation has suggested that the Bis sa'ani community was probably capable of self-sustaining agricultural production under average conditions but was generally incapable of generating any appreciable surplus food products. At the same time, the presence of numerous large kivas, considerable habitation remains, settled villages, and evidence of farming activity suggest that the community was not in some way a specialized transportation-related community. While there appears to have been some local production of decorated pottery in the community, we can identify no other goods or commodities leaving the community as exchange items, with the possible exception of intangible services such as labor. It is nonetheless clear that Bis sa'ani was well-integrated into the larger regional system. Exotic ceramics, timber, various lithic materials, feathers, shell, and even a copper bell were all recovered from the community area. The Pueblo is in line-of-sight with Fajada Butte and other prominent points around Chaco Canyon. A possible signaling feature was located on a small, elevated knoll near Bis sa'ani Pueblo, which could have been used for local communication. A prehistoric road is thought to exit Chaco Canyon and pass through the Bis sa'ani community. These data suggest some form of continuing interaction with communities located within diverse environmental zones within the San Juan Basin.

Community Interaction And The Chaco Halo

It is a positive development that researchers are now thinking not only in terms of regional interaction but also in terms of levels of interaction and site hierarchies (Schelberg, this volume).

Undoubtedly an aspect of Chacoan social organization consisted of different spheres of exchange (Fried 1968), including exchange among the local governing elite groups of the various communities. We would agree with Judge and his colleagues (Judge and others 1981:87) that by Bonito Phase times formal redistribution appears to have overshadowed reciprocity as a means of exchange throughout much of the regional system.

While all of this theorizing is to a certain extent a positive development, we also feel that ultimately our theories must be accountable to the data base that supports them. To this end, we have developed a concept that may be useful to the general understanding of the relationships between the Chaco Canyon communities, the immediately outlying settlements, and the more spatially distant communities. This concept is referred to as the "Chaco Halo," and attempts to take into consideration aspects of site hierarchies, site function, and community interaction (Marshall and Doyel 1981:73-75; Breternitz and others 1982).

Various ecological studies (Schalk and Lyons 1976) and estimates of population density in Chaco Canyon (Drager 1976; Hayes 1981; see Windes 1982 for a more conservative estimate) indicate that the Anasazi population of Chaco Canyon represents a central node into which resources were imported from peripheral communities (Altschul 1978; Judge 1979). However, if we consider the areas directly adjacent to the canyon complex in the lower Escavada, Kimbeto, Betonnie Tsosie, Ah-shi-sle-pah, Kin Klizhin, and Fajada drainages, the potential productivity of the general canyon region is greatly magnified. While archaeological and ecological explorations within these regions directly peripheral to the Chaco Canyon have been limited, informal examinations in the area by Breternitz, Marshall, John Stein and Chaco Center personnel have revealed the presence of numerous rather large settlements. Several of these settlements appear to lack conspicuous evidence of religious or public architecture and may represent large habitation sites; they often exhibit substantial quantities of midden debris. The number, distribution, and characteristics of these sites remain imperfectly known, but it appears that several of these pueblos do not cluster about a local public building as is universal to the peripheral Chacoan communities. Instead, they seem to have been directly allied to the large pueblos of Chaco Canyon proper. Recent investigations by the Bureau of Land Management Chaco Roads Study have demonstrated that a multitude of prehistoric roads enter and exit Chaco Canyon and that the majority of these pueblos are road associated (John Stein, personal communication). These settlements, which apparently occur with discontinuous distribution within the drainages directly peripheral to Chaco Canyon, are recognized here as defining the "Chaco Halo" (Figure 7).

It is probable that the settlements constituting the Chaco Halo served as adjacent agricultural production centers and perhaps seasonal occupational sites for the inhabitants of the central canyon. Many of these sites were also clearly established as a component of the roadway network. The Chaco Halo forms, in essence, an extensive perimeter directly exploited and utilized by certain inhabitants of the central canyon, somewhat analogous to the settlements around the perimeter of nuclear community centers in the outlying districts. Settlements within the Chaco Halo clearly contributed to the productive capabilities of the central canyon and represent a generally unrecognized demographic expression.

The demographic character of the Chaco Halo was dynamic throughout its probable 200-year existence and undoubtedly involved a complex series of land use patterns, the definition of which await further archaeological exploration. By the middle to late Bonito Phase, there was a significant change in the regional settlement pattern indicated by the appearance or expansion of certain scion communities constructed outside of the canyon area, including Bis sa'ani, and various road-associated settlements. These sites tend to express a community pattern of Bonito-style structures surrounded by numerous smaller habitation sites, while great kivas tend not to be associated. These data indicate that the Chaco Halo expanded in both space and complexity to include even more levels of interaction than existed during the early Bonito horizon. Some of these communities may have participated directly in the Chaco Halo support system for the megacommunity while others appear not to have directly contributed to the support of the canyon centers. Our quantitative analyses of Bis sa'ani, for example, revealed that it could not have produced any appreciable surplus subsistence products for distribution into Chaco Canyon

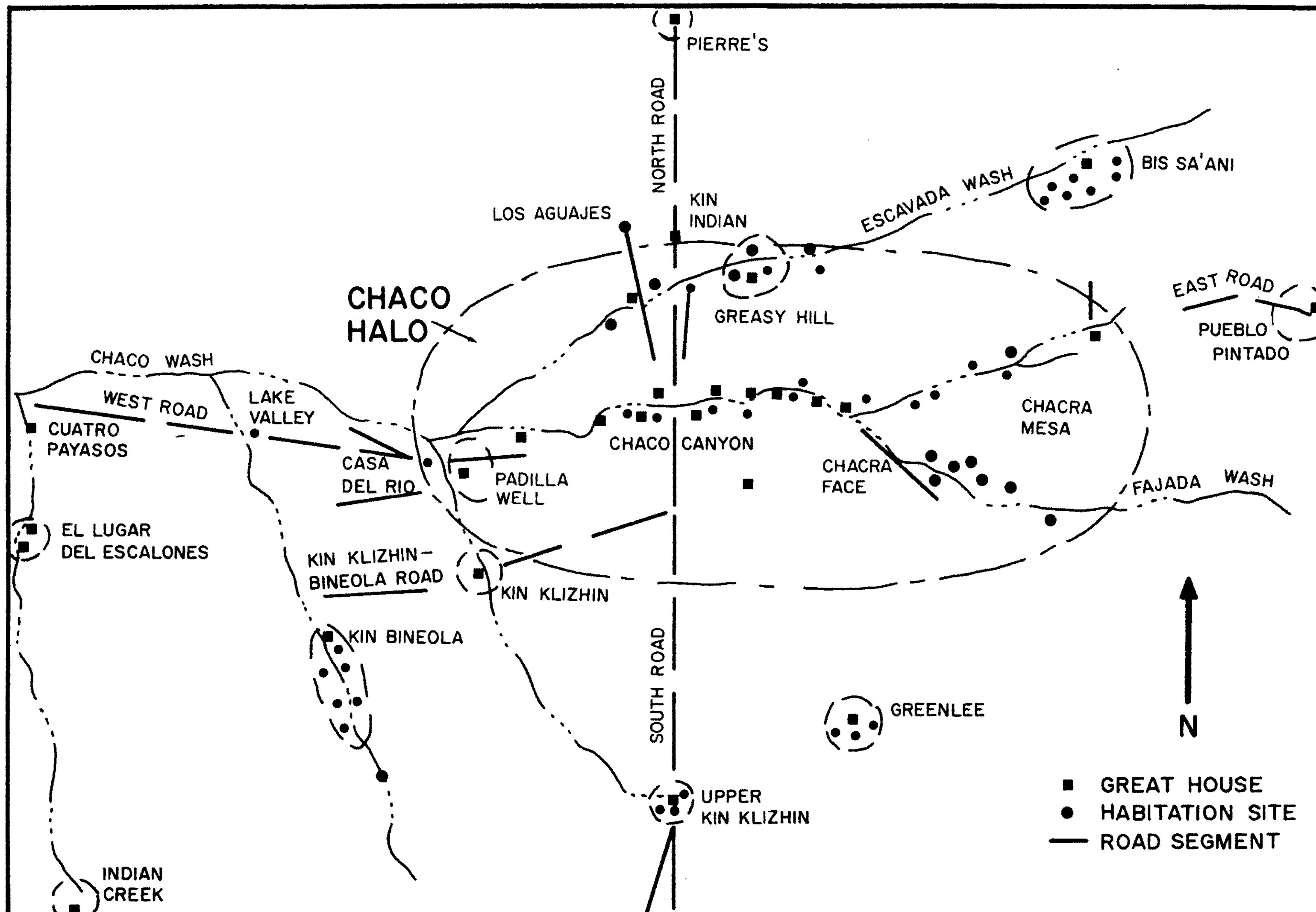

Figure 7. Relationship of Chaco Canyon, peripheral communities and the Chaco Halo.

or elsewhere. Only the gathering of additional comparative data on other communities will allow for further definition of intercommunity relationships both within and outside of the Chaco Halo.

The Chaco Halo is presented here as one possible conceptual device to describe the structure, organization, and interaction of Chacoan communities in one of the most densely populated regions of the San Juan Basin. The Chaco Halo concept attempts to take into account the most recent findings from this intensively studied but always debated core area of Chacoan culture. The concept incorporates recent data from sources as diverse as paleoecology, paleoenvironment, site morphology, settlement pattern, carrying capacity, social organization, community organization, and communicaton networks. The crux of the concept lies in the recognition of the fact that a large number of sites of various types are situated around the periphery of the main Chaco Canyon megacommunity. That these peripheral sites represent a support group for the continued existence of the main canyon community of sites is postulated. The presence of support sites and their associated communities located nearby to Chaco Canyon may account for the relative lack of trash, burials, and living areas associated with the larger Bonito Phase "town" sites in Chaco Canyon. The Chaco Halo model also provides a level of contrast not otherwise obvious in any other regional models that have been proposed. The recognition that several different classes of outlying or peripheral communities (i.e., ancestral and scion, and purely roadway related isolated structures) all may have had different relationships to the main canyon group is an important concept by itself and is certainly deserving of further attention.

The possibility also exists that segments of the Chaco Canyon population may have been dispersed among these sites peripheral to the canyon, as dictated by the annual economic and ceremonial cycle, and thus not concentrated in the large canyon towns on a full-time basis; this model is compatible with the Chaco Halo as proposed (see Judge 1979:903 for a similar perspective). Finally, it is suggested that the Chacoan towns in the main canyon may represent centers utilized and maintained by groups of affiliated communities within the Chaco Halo and the more distant peripheral areas.

From this perspective, we may wish to investigate the possibility that Chaco Canyon as a central place evolved as a product of interaction with the developments in the San Juan Basin in general. Chaco Canyon may be envisioned as a central node developed by the outlying communities to create an intercommunity regional organization. It is then possible that the great pueblos in Chaco Canyon represent regional affiliates representative of certain community aggregates in the outlying provinces (see Marshall and others 1979; Powers, this volume). The hypothesis that Chaco Canyon represents a regional capital composed of rep- resentative centers from various out- lying districts should be tested and evaluated. It is possible that Chaco Canyon could not have existed without the support of the regional provinces.

Discussion

Some authors currently feel that the Chaco regional system was ultimately predicated upon the need to even out scarcity of food resources and to reduce subsistence stress on an extensive scale by a growing population (Judge and others 1981:87). It would appear that many of the settlements involved in the system were in fact located to take advantage of all microenvironments useful to the human populations of the region. Components of the regional system include the San Juan sites, such as Salmon, Aztec, and many others, which had access to aquatic and riverine-associated resources, the Chuska slope group that had access to construction timber and stone and clay resources, and the southern Cibola group that had access to upland resources in the extensive pinyon-juniper zone, as well as land suitable for farming. Doyel (1981) has argued that the evolution of the Chacoan regional system reflects both the dispersed nature of these resources as well as the need to integrate the diversity of resources into a regional redistributional network. The system remained fragile, however, due to the dispersed nature of the resources, and was dependent upon the mutual cooperation of all of the Chacoan regional subtraditions, including the San Juan, Chuska, Cibola and Chaco, in order to insure the survival of the whole system. Centers of power appeared to have waxed and waned through time, an obvious example being the shift to dominance of the San Juan centers over the Chaco by the end of the twelfth century. Also at this time, the populations located in satellite settlements such as Bis sa'ani had just suffered a period of environmental stress due to increased aridity and resource depletion (Betancourt and Van Devender 1981:658; Gillespie and Powers 1983), forcing the abandonment of some marginal outlying localities and reorganization of the remaining members of the regional system.

It is our belief that in order to gain additional support for the above and other models regarding the evolution of the Chacoan regional system certain studies must be emphasized to a degree greater than at present. There must be more research devoted to Chacoan community structure. More specialized and, whenever possible, quantitative studies would be directed towards questions of local agricultural production as well as local specialization of other kinds such as resource procurement or manufacturing. More complete information is needed on regional settlement patterns and on how road systems can and cannot be used to address questions of redistribution and trade. More attention must be devoted to the study of settlement hierarchies and how such hierarchies may have functioned. When many of the above studies have been accomplished, we will all be in a much better position to consider and discuss Chacoan community structure, interaction, and the evolution of the Chacoan regional system.

Acknowledgments

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STANDING ARCHITECTURE AT CHACO CANYON AND THE INTERPRETATION OF LOCAL AND REGIONAL ORGANIZATION

Stephen H. Lekson

Abstract

The standing architecture of the larger sites at Chaco Canyon is examined as evidence of local and regional socioeconomic organization. Changes in plan and building technology at these sites suggest a shift through time from centers of intracanyon or local settlement systems to regional centers. Similarly, the architectural focus shifts from individual buildings to Chaco Canyon itself as a central place. The role of Chacoan building in regional labor organization is discussed; construction labor alone need not have required the importation of a labor force into the canyon. The arguments for "site unit intrusion" of later sites at Chaco are assessed and rejected.

Introduction

After a century of excavation and survey in Chaco Canyon, a new study of Chacoan architecture should be redundant. Oddly enough, this is not true. The most extensive field studies of Chacoan building were the earliest (Jackson 1878; Holsinger 1901), undertaken before the development of tree-ring dating, while the most important dendrochronological studies (Bannister 1965; Robinson and others 1974) were accomplished without the benefit of concurrent field work. The Chaco Center has provided an opportunity for field analysis of the ruins (Lekson 1978; Lekson and McKenna 1980; Hayes 1981) and the reinterpretation of the dendrochronology in light of that field analysis (Lekson 1983; Lekson in prep.)

This paper is limited to the confines of the canyon and to only those aspects of architecture in Chaco Canyon that have clear regional implications. The presentation is chronological. Chacoan building can be divided into four tree-ring dated periods: A.D. 900-940, 1020-1050, 1050-1075, and 1075-1130.

Architecture defines the Chacoan region. The region coincides with the location of "outliers" that exhibit Chacoan building characteristics. Which characteristics, and how many, and in what combinations are happily not my concern (Marshall and others 1979; Powers this volume).

I had hoped that by limiting the study to Chaco Canyon proper I could avoid arguments about various sites' Chacoan credentials; but even within the confines of Chaco Canyon, terminological quibbles arise. Some problems, such as the "McElmo" problem, are nonproblems (as I will discuss below). However, the separation of "large" and "small" Chacoan sites is less clear than we might wish (Truell 1981; Lekson and Newren in prep.). The traditional list of large sites includes Penasco Blanco, Casa Chiquita, Kin Kletso, New and Old Alto, Pueblo del Arroyo, Pueblo Bonito, Chetro Ketl, Tsin Kletzin, Hungo Pavi, Una Vida and Wijiji (Figure 1). But the smallest of these ruins are no larger than other, more heavily reduced sites that went unnoticed and unnamed by Jackson and Holsinger. Sites such as Hillside Ruin (Judd 1964:146), the Headquarters Site (Vivian and Mathews 1965:81), and the Talus Unit (Bannister 1965:194) are likely candidates for elevation. However, for this paper the discussion will be limited to the traditional large Chacoan ruins.

Large Chacoan sites have been classed together as "towns," "great houses," "Chacoan structures," or "Bonito Phase sites." However the list is drawn, there are only a dozen or so "large" sites in the canyon. The importance of hammering out a generic tag for such a small group escapes me, but terminological arguments are long-standing and cannot be avoided entirely.

Vivian and Mathews (1965) introduced two parallel systems for differentiating the large from the small: the "town-village" dichotomy, and a phase system that will be discussed later. The large sites are "towns" and the smaller sites are "villages." Although they felt that the differences could be traced to Basketmaker III, the "town-village" dichotomy was defined with the initial large site construction of the early A.D. 900s.

A.D. 900-940

Construction of "towns" began in the early A.D. 900s, at Penasco Blanco, Pueblo Bonito, and Una Vida (Figure 1). At these three sites, early A.D. 900s buildings were large, multistoried, arc-shaped structures (the "dog-leg" at Una Vida reflects constraints of the building site). The three buildings were remarkably similar in plan (Figure 3). If the excavated portions of Pueblo Bonito are typical, all three buildings probably had a line of large circular pit structures in the plaza. Behind them were a row of large ramada/living rooms, a second row of large featureless rooms, and in the rear, a third row of smaller storage rooms. At Pueblo Bonito, the above ground rectangular rooms form suites, each suite consisting of a ramada-living room, a large room, and paired storage rooms (Figure 2A). The number of pit structures suggests that each pit structure was associated with two or three suites. Each structure was built in a series of construction events, or "programs." At Pueblo Bonito, each program consisted of four or five suites.

The pattern of rooms in suites is similar to contemporaneous smaller sites at Chaco (Newren in prep.) and, in fact, throughout the surrounding area. Large, early A.D. 900s structures seem to be dramatically scaled-up, massively built versions of the smaller contemporary domestic buildings in the San Juan Basin.

What are the early "towns" and what is their place in the region? Vivian and Mathews (1965) felt that towns and villages represented ethnically distinct local populations with substantially different settlement forms and subsistence strategies. Our analyses do not support Vivian and Mathews' conclusions, but they may have been correct in their areal scale: the appropriate context for understanding these early buildings may not extend beyond Chaco Canyon. There are three locations where major side drainages enter the canyon: the Fajada area (Vicente Wash and Gallo Wash), South Gap, and the confluence of the Chaco and the Escavada (Figure 1). Large structures were built at each of these locations in the early A.D. 900s: Una Vida across from Fajada, Pueblo Bonito opposite South Gap, and Penasco Blanco on the bluffs overlooking the confluence of the Chaco and the Escavada. These sites occupy strategic locations and may be central to communities of smaller, contemporary buildings (Judge and others 1981). The simplest interpretation of early Chacoan buildings is that they are scaled-up domestic structures, housing groups that are themselves of some strategic importance and centrality to their surrounding communities. The three earliest Chacoan "towns" may have housed local (intracanyon) elites that together made up at most about 10-15% of the canyon population. They were in some sense "central places" within the canyon settlement system, or more accurately, within three distinct settlement systems.

Tree-ring dates (which for all periods are less than a 0.2% sample of the structural wood used in large Chacoan sites) suggest an 80-year hiatus in construction following the early A.D. 900s building. Several lines of evidence suggest that this hiatus may be more apparent than real. There are a few tree-ring dates at Hungo Pavi from the second half of the tenth century, including a cluster of dates about A.D. 990-1010. The position of Hungo Pavi is similar, but not identical, to that of the early 900s structures: Hungo Pavi is located at the mouth of Mockingbird Canyon, a large side canyon midway between Una Vida and Pueblo Bonito (Figure 1). It appears that a structure similar in scale to the early A.D. 900s buildings was constructed at Hungo Pavi in the late A.D. 900s-early 1000s. While initial construction at Hungo Pavi may have been of similar size, it was definitely different in form. The early 900s buildings were arcs, but Hungo Pavi was an elongated rectangle. The difference is significant because subsequent large-scale building was also rectangular.

A.D. 1020-1050

The next major construction was at Pueblo Alto, Chetro Ketl and Pueblo Bonito. Building at Pueblo Alto and Chetro Ketl repeated the early A.D. 900s

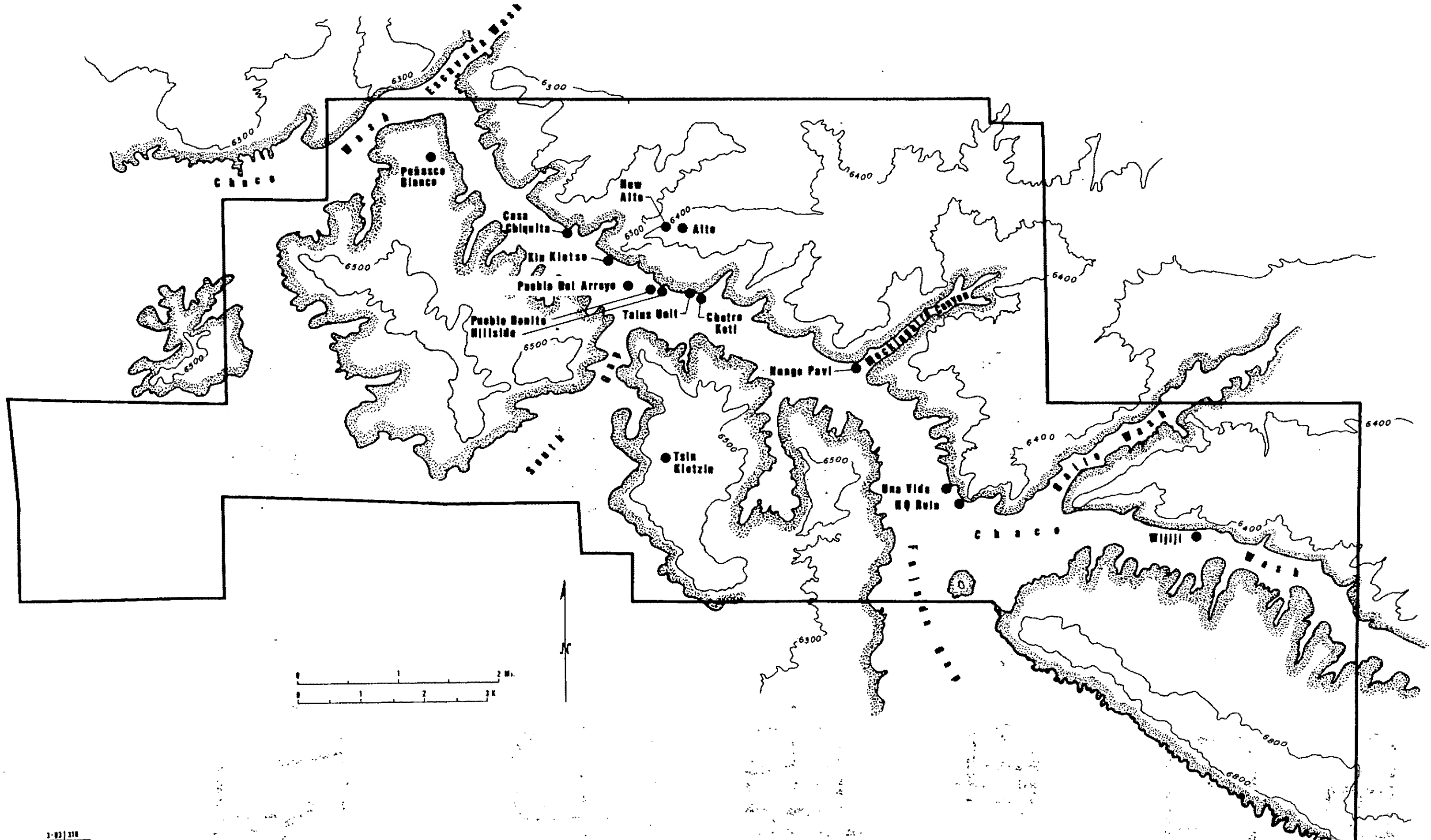

Figure 1. Chaco Canyon, New Mexico.

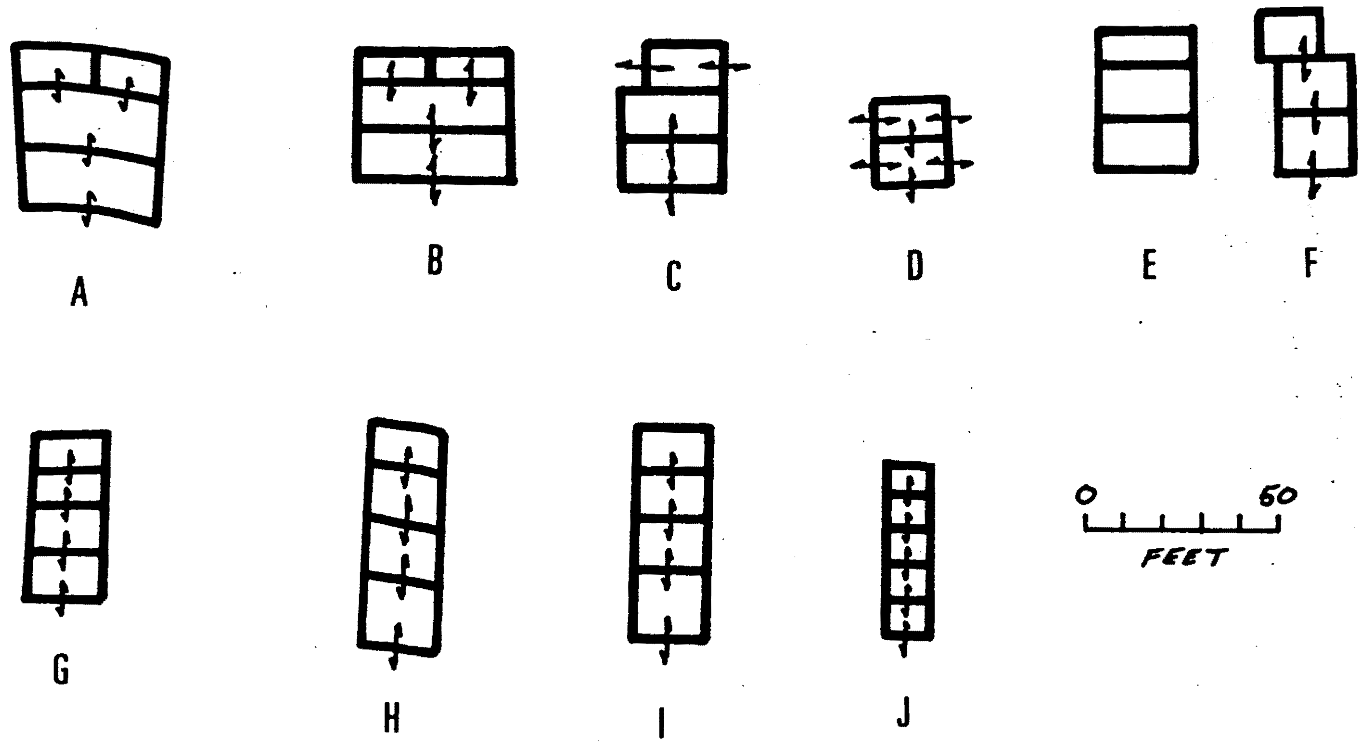

Figure 2. Selected room suites: A-Pueblo Bonito (920-935), B-Pueblo Alto (1020-1040), C-Pueblo Alto (1050-1060), D-Pueblo Bonito (1050-1060), E-Chetro Ketl (1050-1055), F-Pueblo del Arroyo (1065-1075), G-Pueblo Bonito (1060-1075), H-Pueblo Bonito (1075-1085), I-Pueblo del Arroyo (1095-1105), J-Wijiji (1105+).

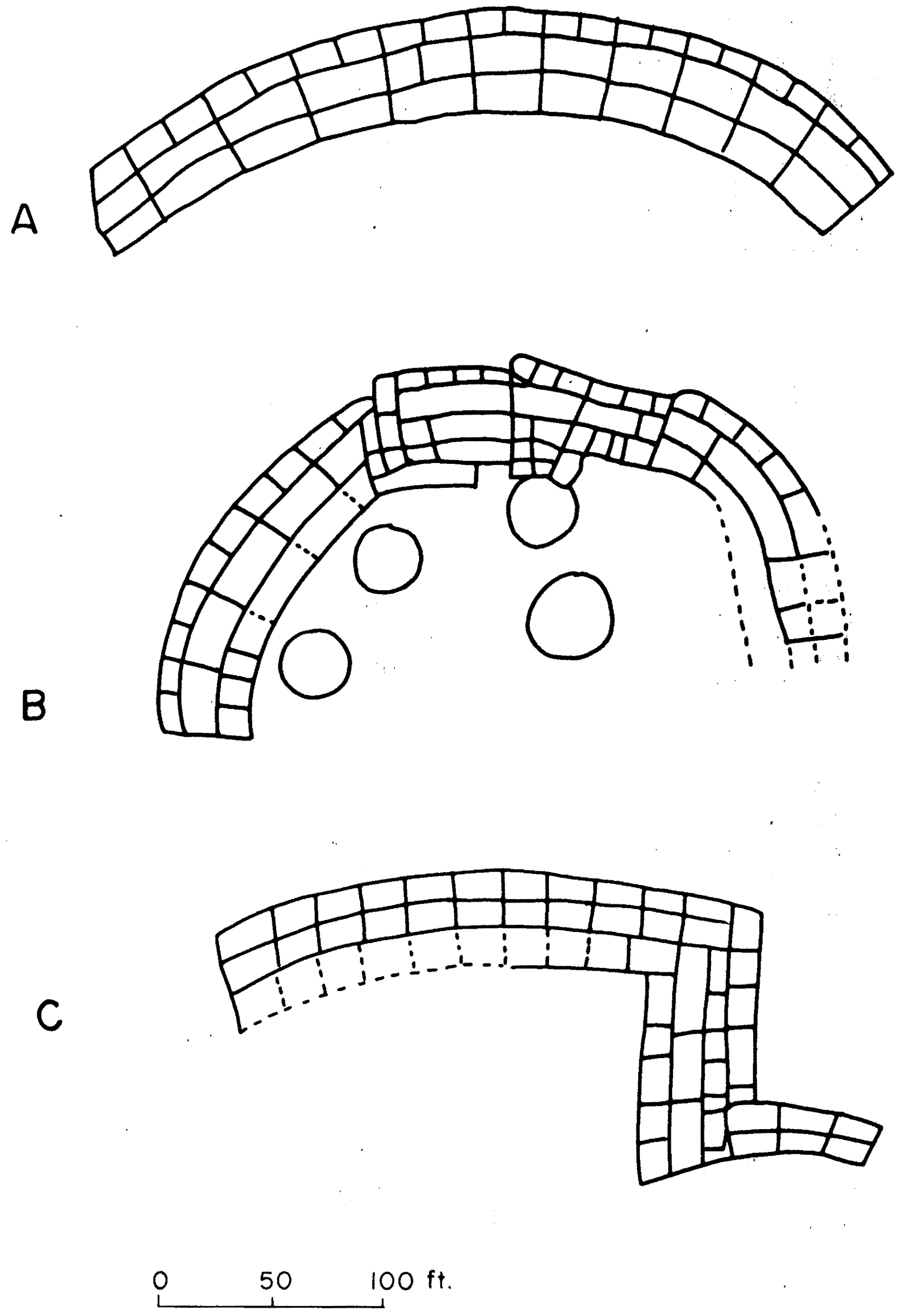

Figure 3. Early A.D. 900s building: A-Penasco Blanco, B-Pueblo Bonito, C-Una Vida.

unit of pit structure, large rooms, and paired smaller rooms (Figure 2B). At Pueblo Alto and Chetro Ketl (Figures 4A, 4B), the early A.D. 900s pattern was straightened out into elongated rectangles. At Pueblo Bonito (Figure 4C), the earlier A.D. 900s building was simply enclosed in an exterior row of storage rooms, with little alteration of the earlier building. The architectural forms of the early A.D. 900s appear to continue in A.D. 1020-1050 building.

There is, however, an important discontinuity in A.D. 1020-1050s building. Where structures in the early and later A.D. 900s occupied separate, presumably strategic locations, new buildings in the A.D. 1020-1050 period did not. Chetro Ketl is a close neighbor of Pueblo Bonito, with which it shared the key South Gap locale (Figure 1). Pueblo Alto was located on the plains to the north, outside the canyon entirely. Both of these sites were nearly identical to the buildings of the early A.D. 900s, which I suggest were local elite residences, but both lack the architectural context of strategic locale and associated communities of smaller domestic sites.

A.D. 1050-1075

Construction during this period was limited mainly to additions to existing buildings. At first, these were added on as wings (Figure 5), but later in the period, they took the form of less symmetrical additions, extensions and modifications. Only one new structure, Pueblo del Arroyo, was started, again at South Gap near Pueblo Bonito (Figure 1); initial construction at Pueblo del Arroyo was very similar in scale to other A.D. 1050-1075 construction programs.

Although individual building programs from A.D. 1020-1050 and A.D. 1050-1075 were all about the same scale, the sequencing of those programs steadily increased the yearly labor requirements for construction. That is, more was being built each year.

If new rooms equal new population, the annual rate of population growth for Chaco Canyon from A.D. 700 to about 1140 was about 0.3% (using Hayes' 1981 estimates as the population maximum for each phase). However, the rate at large sites, considered separately, was much higher. At Pueblo Bonito, the growth rate (similarly estimated) was about 2.25%. Hassan (1981:201) notes that Neolithic growth rates vary from 0.1 to 0.5%. While the canyon as a whole falls within this range, something was going on at the large sites that cannot be attributed to internal population growth alone. Perhaps the canyon population was aggregating in these structures, or perhaps rooms at larger sites equal something other than new population.

Probably by A.D. 1050, and certainly by A.D. 1075, the A.D. 900s building form had given way to elevated circular rooms or "kivas" with no clearly associated rectangular room suites. Size differences between front- and rear-row rooms, marked in the A.D. 900s and early 1000s, are either greatly reduced or absent (Figures 2C-2F).

Elevated circular rooms are almost diagnostic of later Chacoan building. They have been called clan kivas, raised kivas, and even tower kivas. I reserve "tower kiva" exclusively for multistoried circular rooms (and not for one-story circular rooms built on the second-story level). But the term kiva itself is a misnomer, if by "kiva" we impute a function similar to ethnographic kivas. I suspect that the elevated circular room continued many of the basically domestic functions of earlier pit structures, and that Great Kivas found in the plazas of large sites are more likely prehistoric analogs for the modern kiva. But this argument is beyond the scope of this paper, and I will continue the use of "kiva" here for convenience.

A.D. 1075-1115

Formal change and the accelerated pace of construction come to a peak in the period A.D. 1075-1115--in fact, A.D. 1075 can be considered a watershed in Chacoan building. From A.D. 1075 to 1115, there were only six major construction programs (the east and west wings of Pueblo Bonito; the three-story row of storage rooms added to the rear of Penasco Blanco; the north and south wings of Pueblo del Arroyo; and Wijiji; Figure 6). These six programs are truly massive; all are three to four times larger than building programs of the preceding periods. They seem to have been sequential--a program was completed about every 7 to 10 years with minimal overlap--but even so, yearly levels of labor were

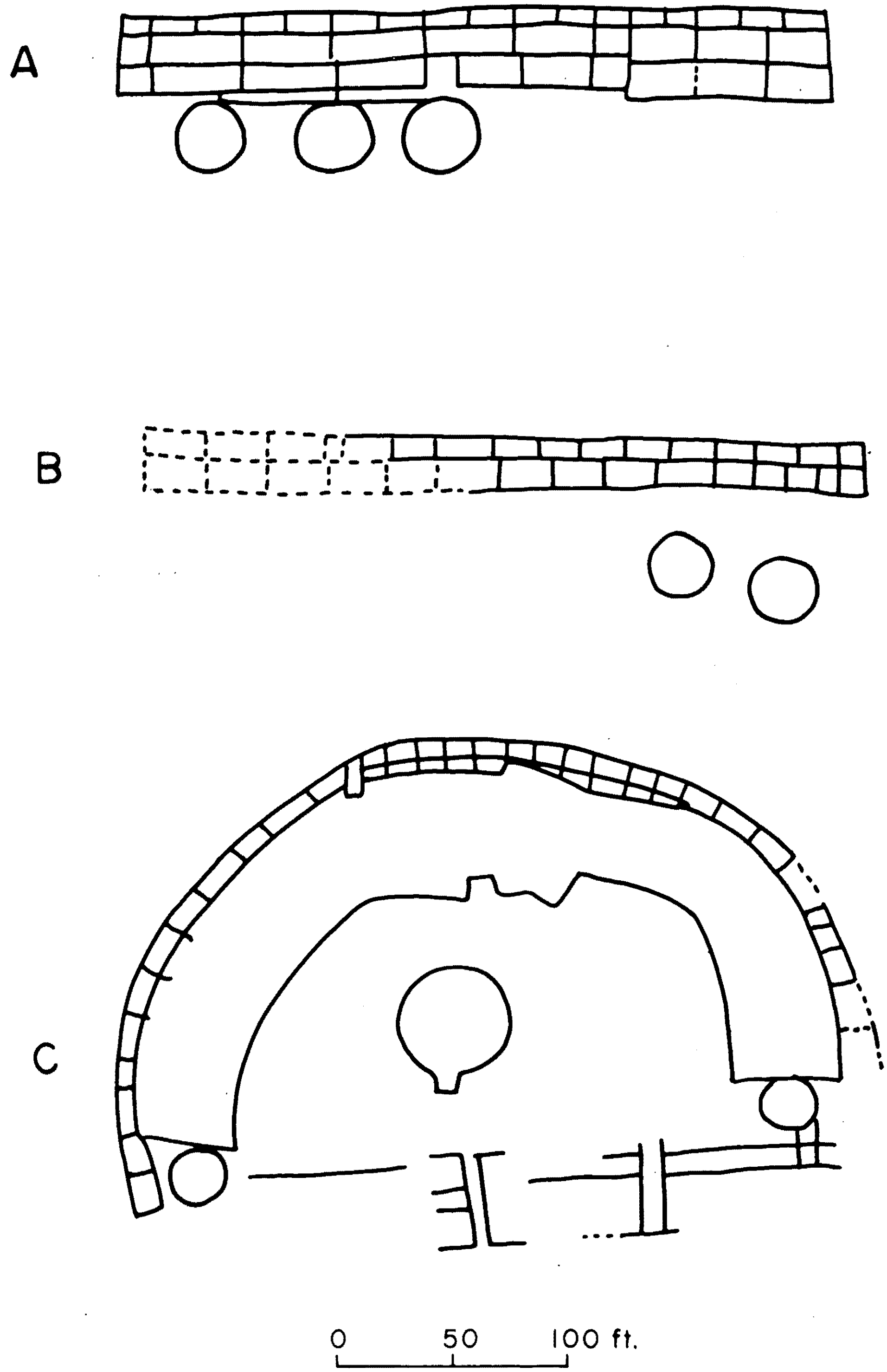

Figure 4. A.D. 1020-1050 building: A-Pueblo Alto, B-Chetro Ketl, C-Pueblo Bonito.

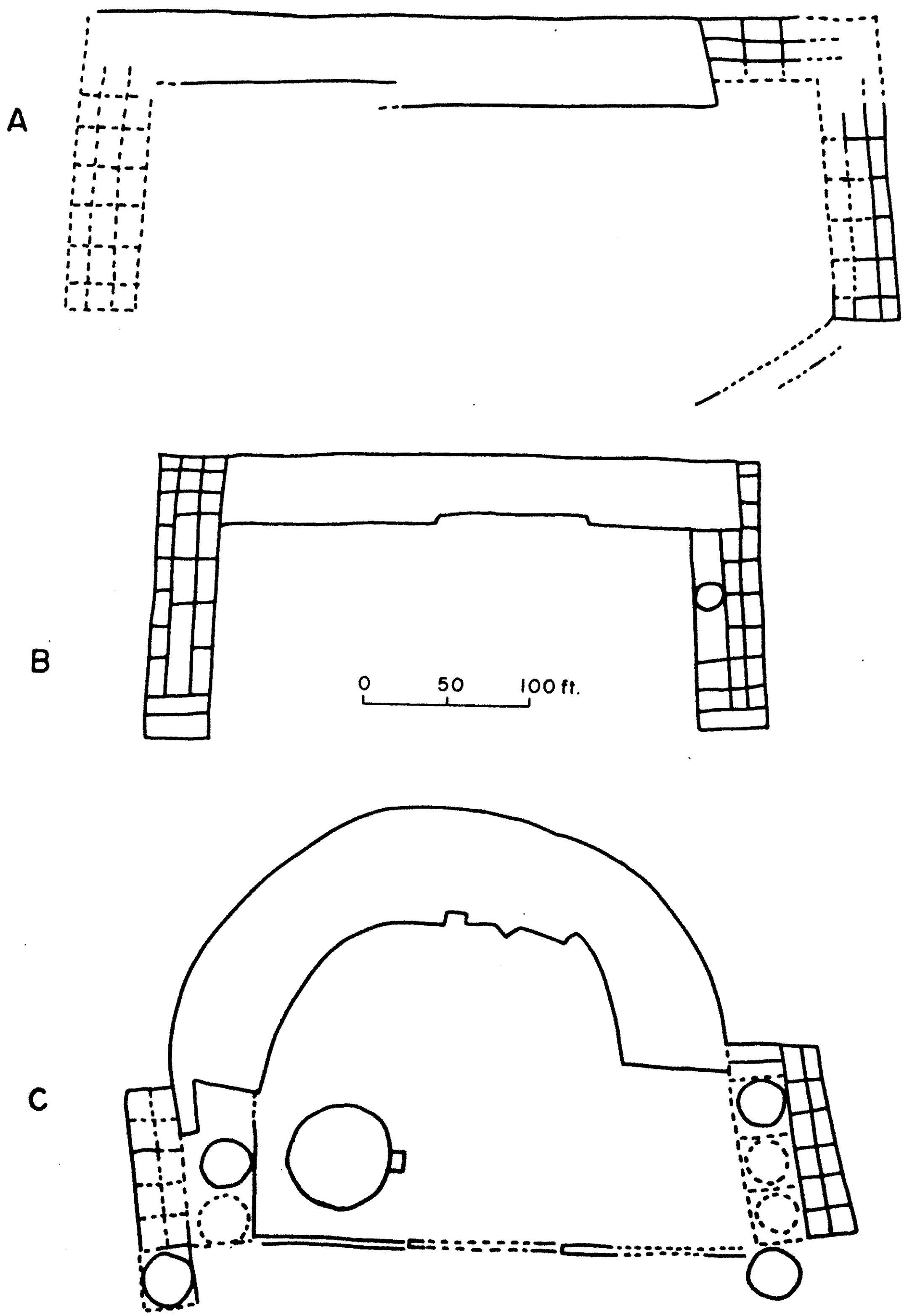

Figure 5. A.D. 1050-1075 building: A-Chetro Ketl, B-Pueblo Alto, C-Pueblo Bonito.

twice that of the A.D. 1050-1075 period.

How are we to interpret this level of architectural labor at Chaco? I have heard some scholars (revisionists? reactionaries?) talk of Chacoan building as a quaint and antique form of the historic Pueblo, built by small kin groups. I have also listened to Chaco enthusiasts, unofficial members of the Chaco Chamber of Commerce, who are staggered by the labor expended on these buildings and see in them evidence for a regional corvee, almost like the Pyramids. These views on labor are polar, but I have never heard either supported by quantified estimates. We need to establish at least the order of magnitude of labor expenditure before Chacoan architectural labor can be assessed.

I have elsewhere estimated the total labor represented by construction stages at large sites at Chaco (Lekson in prep.). I originally hoped to arrive at maximum and minimum values, bracketing the labor invested in Chacoan building, but a little reflection showed that minima and maxima are less useful than they might appear. Some absolute minimum value might be reached, using the world record for brick laying or weight lifting; but it is difficult to envision complementary maximum values: how slowly can one person lay masonry? Or how little can one person lift or carry? My own experience suggests that even simple building maintenance tasks, like cleaning gutters, can span several administrations. The practical difficulties of establishing maxima fatally undermined the minimum/maximum scheme, and the alternative adopted was the estimation of reasonable or plausible rates. Plausible arguments are not strong arguments, but in this case, when the goal is defining a realistic scale for the problem, plausible rates are not only Hobson's choice, they are actually appropriate. The rates I have used are not the "correct" rates, but they are broadly relevant to the scale and type of building at Chaco. This is one major problem obstructing our interpretations of Chacoan construction.

Assuming that reasonable rates can be established, another serious problem in interpreting labor input is scheduling. A figure of 5000 man/days can mean one man for 5000 days or 5000 men for one day. Construction labor can be divided into four general types representing an approximate sequence: cutting and processing beams, transporting beams (discussed briefly later in this paper), quarrying stone and procuring other masonry materials, and actual building.

How was this sequence of labor scheduled? The only hints of this type of information come from Chetro Ketl and Pueblo Alto. The extensive tree-ring sample from Chetro Ketl suggests some points about wood procurement; most or all of the wood used in one well-sampled room at Chetro Ketl was cut over a very short period of time, perhaps a matter of weeks (Bannister and Robinson 1978). Most wood at Chetro Ketl was cut in the spring or early summer (Dean, in Lekson 1983). From Pueblo Alto, there is faunal evidence for the span of construction: the minimum number of years for construction of the north or central wing of Pueblo Alto may have been three, with activities again mainly in the spring (Akins 1982:146).

To illustrate a hypothetical analysis of labor scheduling during the A.D. 1075-1115 peak and its implications, I will discuss the construction of a single large building program, the east wing of Pueblo Bonito. The east wing of Pueblo Bonito (Judd's Type IV East Wing; Figure 6A) is the largest single construction event in the Chaco sequence.

Using rates detailed elsewhere (Lekson in prep.), construction of the east wing of Pueblo Bonito required about 193,000 man/hours (MH). Half of this labor represents tree cutting and transport, and masonry material procurement. The other half is actual construction (masonry, mixing and carrying mortar, installing roofs), and only a small part of that half requires skilled labor (shaping and laying stones).

To hypothetically reconstruct the sequencing of this labor, I assume a 10-hour work day and a 30-day work month. To cut and process all the timber in a period of one month requires about 30 men, or 30 man/months. I will use 30 man/months as a basic unit for all other activities. In 30 man/month units, construction activities had the following requirements: cutting trees, 1; transporting beams, 6; quarrying etc.,3; construction, 10.8.

I have further assumed that the east wing was completed within 10 years (approximately the mean span of A.D. 1075-1115 construction programs), with the actual construction taking no more than three years (as suggested by the Alto data). Given a 10-year total span and three years for actual construction, the labor requirements can be apportioned as in Table 1. In words, a crew of 30 could cut and transport beams for one month every year for seven years, and quarry and construct for four months every year for three years, and build the single largest construction program at Chaco.

But construction was going on at more than one site at a time. What do simultaneous construction programs imply for Chacoan labor organization? Labor for all construction programs was summed and apportioned in five-year segments. The five-year interval with the highest MH figure was A.D. 1095-1100, with an average of 55,645 man/hours per year--about three times the yearly levels suggested above for the east wing of Pueblo Bonito. What does 55,645 man/hours per year mean?

A total of 55,645 man/hours is 5,565 10-hour man/days; if Chacoan builders worked a 365-day year, 5,565 man/days could be generated in a single year by a labor force as small as 16. Of course, this intensity of labor is extremely unlikely; it illustrates the reductio ad absurdum possible in the analysis of labor estimates divorced from cultural context.

Ford (1968) estimates the yearly labor requirements of San Juan Pueblo ca. 1890. Although San Juan Pueblo is far removed from Chaco, the budget of labor at San Juan is instructive for the evaluation of Chacoan building. Out of a total population of 400, Ford estimates a work force of 212, representing a potential total of 1,857,120 hours per year (212 x 24 x 365). The largest organized labor event at San Juan was the annual cleaning of the irrigation ditches; this required over 100 workers for four long (10-hour) days, or about 0.23% of the work force's total time (1,857,120 hours). Let us use 0.23% as a hypothetical labor investment in Chacoan building.

The required rate of 56,000 man/hours per year is 0.23% of 24,347,826 man/hours per year; translated into people, 24,347,826 man/hours per year could be generated by 2,779 workers. Given a ratio of 212 workers to a total population of 400 at San Juan, 2,779 suggests a total population of about 5,243 at Chaco. This is alarmingly close to Hayes' (1981:51) peak population estimate for Chaco of 5,652. The near agreement of these two figures should not be taken too seriously; for one thing, many of the rooms and buildings figuring in Hayes' population calculations were not yet built at A.D. 1100, and recent analyses suggest somewhat lower population levels than those calculated by Hayes. However, lower population figures do not require a substantially more organized labor force. A population half the size of Hayes' maximum would require eight, rather than four, days of work in the same framework of San Juan ditch cleaning.

It is unlikely that Chacoan building was organized as was San Juan ditch clearing. But it is evident that Chacoan building did not require specialization of appreciable segments of the population, or corvee labor from outlier communities, or any of the other unlikely suggestions occasionally heard from enthusiasts of Chacoan architecture. These reasonable, plausible estimates can be doubled, tripled, or even quadrupled and there would still not be any rational cause to consider building a major problem for local, much less regional, labor organization.

It would be wrong to totally discount the labor represented by Chacoan building. Labor was undoubtedly well organized, and it is significant that the little evidence we have points to building activities occurring in the spring (Akins 1982; Dean in Lekson 1983) during the planting season. Architectural labor was considerable and, significantly, it was considerably more than was expended on contemporaneous small sites. Some aspects of building at Chaco Canyon had important regional implications, for materials if not labor. Using a constant of beams per square meter of roof, I estimate that the large sites in the canyon required over 215,000 trees (Dean [in Lekson 1983], using a different set of assumptions, estimates 200,000 trees). The vast majority of these beams did not come from the area around Chaco; they probably came from the forests behind Kin Ya'a, Pueblo Pintado or perhaps Skunk Springs. (The distances required for beam procurement were, of course, incorporated in my labor estimates.) Wood was certainly a bulk item coming into Chaco from the surrounding region; perhaps it was the bulk item.

What are the large Chacoan buldings of the late eleventh and early twelfth centuries? The form and building technology of these structures offer clues to their functions. The large structures at

Table 1. Hypothetical labor schedule in 30 man/month units for construction of the East Wing of Pueblo Bonito.

	Years									
	1	2	3	4	5	6	7	8	9	10
Cutting	1									
Transport		0.9	0.9	0.9	0.9	0.9	0.9			
Quarry								1	1	1
Construct								3.6	3.6	3.6

Chaco were clearly more "expensive" than the small sites at Chaco (Lekson and Newren in prep.), and more "expensive" than most other Anasazi buildings. They are more substantially built (and consequently better preserved) than other contemporaneous building. Some of the massiveness is no doubt required by multistoried design; some of the massiveness may be for show. But it also seems likely that some of the massiveness in Chacoan construction reduced maintenance. Perhaps the labor force available for upkeep was disproportionately small--"caretakers," or perhaps the residents were above replastering and reroofing after every rainstorm--elites. In any event, after seven centuries of nonmaintenance, the larger buildings were surprisingly intact while their smaller neighbors were reduced to low bumps on the landscape.

A.D. 1075-1115 building created a tremendous number of interior rooms. The buildings were massive blocks; the east wing of Bonito is up to five rows deep and four stories tall. Most of the rooms created would not have enjoyed direct access to the exterior. Some construction retained a front-to-rear pattern that recalls the earlier units (e.g., Figure 2g), and at each building several of these units seem to be associated with an unusually large circular room. However, most rooms interconnect in both axes, and size differences from front to rear are minimal. The exception to this pattern of massive blocks is Penasco Blanco (Figure 6B), where A.D. 1075-1115 building added a row of rear rooms without corresponding additional domestic construction.

Presumably, interior rooms were not normal domestic rooms. They are generally labeled storage, which seems a reasonable guess. In short, from A.D. 1075 to 1115, a very great amount of potential storage space was created--much greater than would have been required by contemporaneously constructed domestic rooms (compared to earlier ratios of domestic to storage space). And these storage rooms were constructed in the most costly, planned building programs in the Chacoan sequence. These buildings, and the labor required to build them, suggest the nature of Chacoan building was changing from elite residence alone to large storage facilities with continued elite occupation.

A.D. 1115-1140(?)

Following this period of intense building, construction programs return to the pre-A.D. 1075 level. Construction continues at existing buildings but most takes place at new sites. The new buildings are the so-called McElmo Phase structures (Figure 7). McElmo sites might have rather important regional implications: they were originally interpreted as site-unit intrusions from the San Juan River area.

Vivian and Mathews (1965) define three phases to complement the broader "town-village" terminology. The Hosta Butte Phase was the villages. Towns were split into two groups, the Bonito Phase and the McElmo Phase. It is the McElmo phase that is of interest here. If we can define the sites of the McElmo phase, then the remaining large sites are, by default, the Bonito Phase. The McElmo Phase was defined by nine "factors" (Vivian and Mathews 1965). These are: dates (including the predominant ceramic types), architecture, masonry, length of occupation ("development"), lack of Great Kiva ("ceremonial"), presence of tower kivas, presence of tri-walled structures, richness of artifact inventory, and lack of association with water control features. For reasons developed elsewhere (Lekson in prep.), the latter five factors can no longer be considered to specify "McElmo" sites. Only dates, architecture, masonry, and length of occupation will be discussed here. Dates and length of occupation are two aspects of one thing; despite some earlier tree dates, I suggest that the McElmo sites were built and occupied after A.D. 1115 (Lekson in prep.). But construction and occupation continued at almost all large Chacoan sites after A.D. 1115. Rather than specify a particular phase, the date and length of occupation simply indicate post-A.D. 1115 Chacoan building at new sites. What is left of the original factors (and, among many archaeologists working in the San Juan Basin, represents definitive criteria in "McElmo" arguments) are carbon painted pottery, a particular masonry style, and a compact ground plan. Traditionally, these have been considered characteristic of the San Juan area.

The "McElmo" assemblage of carbon painted types (which includes locally made wares, Arizona wares and Chuska wares, in addition to San Juan types) is found in all Chacoan sites occupied at

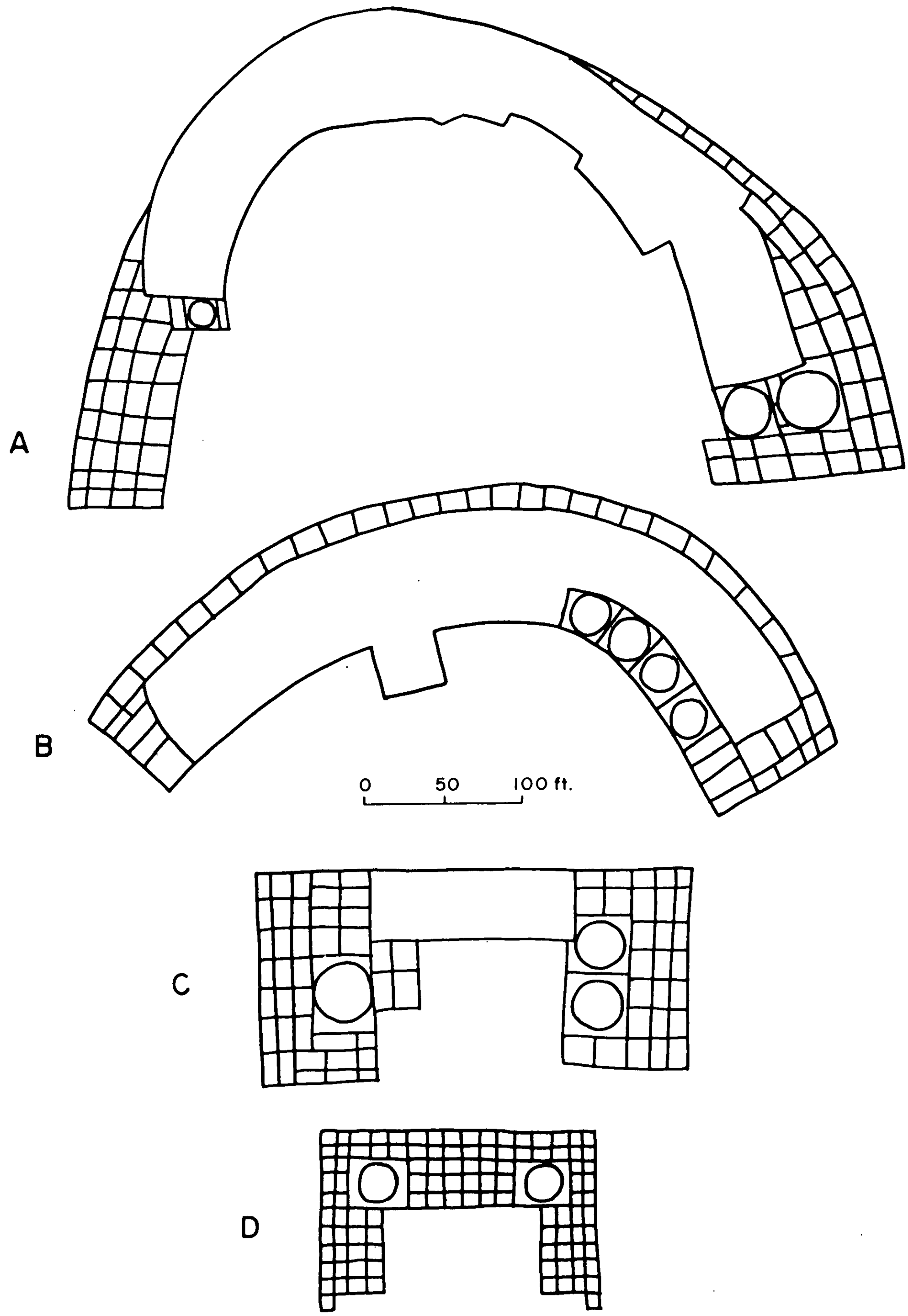

Figure 6. A.D. 1075–1115 building: A–Pueblo Bonito, B–Penasco Blanco, C–Pueblo del Arroyo, D–Wijiji.

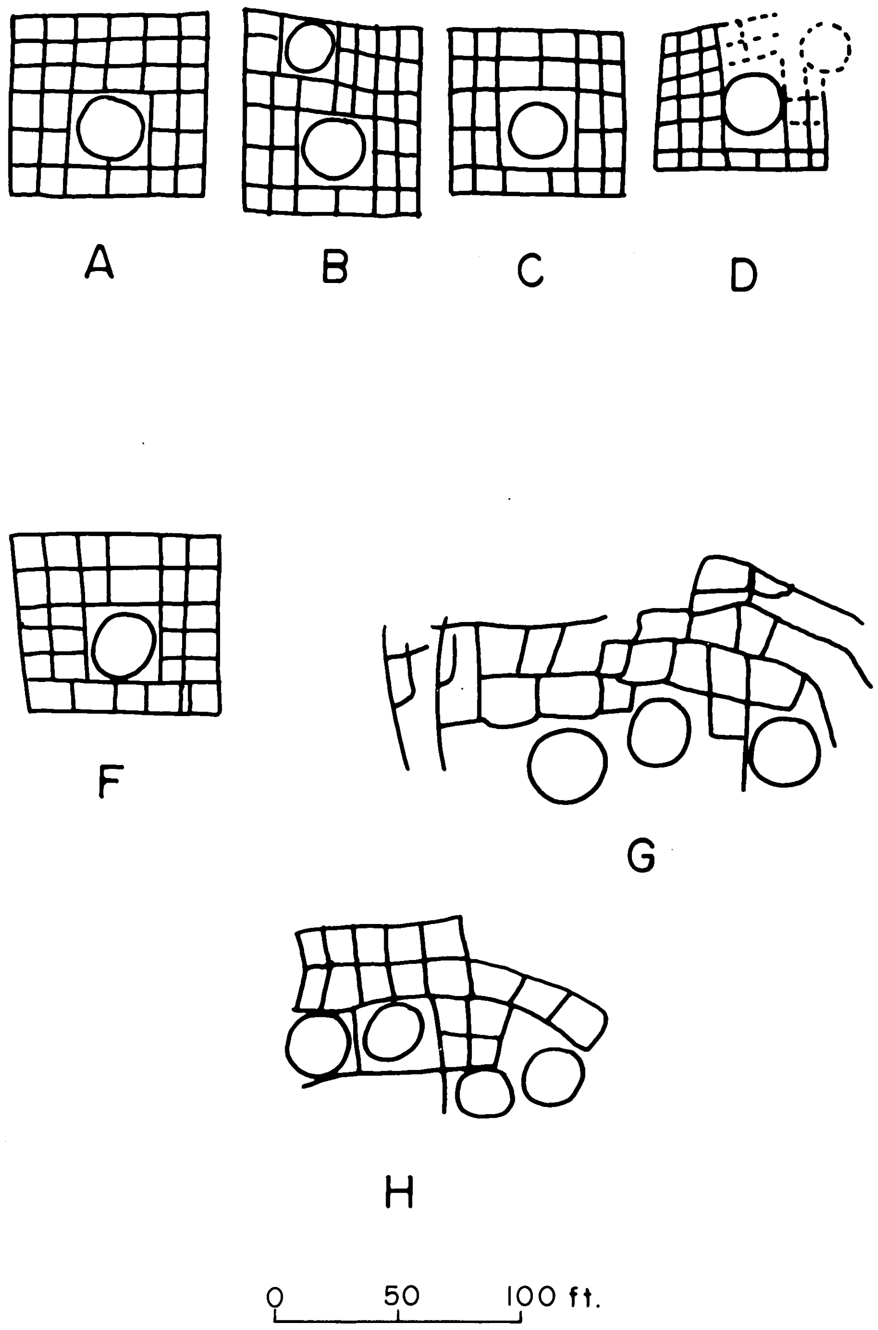

Figure 7. A.D. 1115+ building: A-New Alto; B-Kin Kletso, west; C-Kin Kletso, east; D-Casa Chiquita; E-Rabbit Ruin, west; F-Escalante Ruin; G-Big Juniper House; H-Bc 50.

this time. The masonry style appears in post-A.D. 1100 construction programs at other large sites (and may be earlier in Chaco than in the San Juan); it is probably more a response to diminishing supplies of easily procured tabular sandstone than a cultural marker. The compact ground plan also appears in A.D. 1115-1140 additions to existing sites (Lekson in prep). The use of this plan as a San Juan diagnostic is particularly interesting. The ground plan of New Alto (Figure 7A) supposedly suggests San Juan intrusion; the same ground plan at Escalante Ruin (Figure 7F) is today taken to indicate a Chacoan outlier (Hallasi 1979). The McElmo Phase at Mesa Verde (where the term originated) includes sites like Big Juniper House (Swannack 1969); the ground plan of this site is much more like that of Bc 50 at Chaco than Kin Kletso and other 1115-1140 Chacoan sites (Figures 7G, 7H). The "McElmo Phase," as it has been used at Chaco, specifies only buildings constructed on new sites from 1115-1140; otherwise, it seems of little use. Certainly the notion that McElmo sites represent "site-unit intrusions" from the San Juan is no longer tenable.

Also appearing during this period are numerous specialized structures, almost certainly nondomestic, such as tower kivas, tri-wall structures, and probably many roadway related buildings (John R. Stein, personal communication). In short, by the early A.D. 1100s a great variety of large and small buildings existed in the canyon; and in terms of simple room counts, about half of the rooms in the canyon were in the larger buildings.

The Architectural Context Of A.D. 1075-1140 Building

Recall that Chacoan buildings of the early A.D. 900s may have been central places for local settlement systems and perhaps the residences of local elites. If we assume that the large Chacoan buildings continued an elite residence function, the settlement hierarchy at Chaco in the late A.D. 1000s and early 1100s was very top heavy; there are about as many rooms in large sites as there are in smaller buildings. But it is probably incorrect to equate a room in a large site with a room in a smaller site as a population index. Hayes (1981), using the number of rooms, suggests a population of 2,763 for the large sites. Using an index based on the numbers of kivas, rather than the number of rooms, I estimate only 1,300. Windes (this volume), using floor features, arrives at an even lower figure, but Windes denies upper-story living room features and therefore his estimate may be slightly low. Associated wall features, such as niches, suggest at least a small proportion of upper-story rooms were in fact living rooms (Lekson in prep.).

After A.D. 1075 (and perhaps before), a great many of the rooms at larger sites were probably neither domestic units nor storage rooms associated with domestic units. This may indicate an added public function to the possible previous function of elite residence. But even considering alternate functions for post-A.D. 1075 buildings, potential elite groups housed in the larger sites were a disproportionate segment of the canyon population, if we are to continue to consider them local elites.

At some point, the centrality of the larger Chacoan sites expanded beyond the limits of the canyon and its immediate surroundings. I feel the architectural evidence for this shift points to a period after A.D. 1050 and before 1075--1075 marks the beginning of the most massive construction programs, suggesting that a regional system was already in full operation (both requiring the addition of central storage space and supporting their construction). Presumably, Chaco had become central to a region, and the functions of the larger buildings at Chaco had shifted from central places within the canyon to buildings in a cohesive larger settlement, itself central to both a core area around Chaco and a much larger area approximating the San Juan Basin (Powers this volume). This view is supported by the late proliferation of building types, and their high density in the central canyon during and after the A.D. 1115-1140 construction period. In a 3-km length of the canyon (Figure 8), the built environment was nearly continuous and included stratified housing, public ceremonial architecture, community storage facilites, extensive boundary walls, roads, and road features.

For this later period, the "town-village" terminology is misleading. Several "towns" are literally a stone's throw apart, and the "villages" are cheek-by-jowel. Rank-order analyses and hierarchies of settlement size that con-

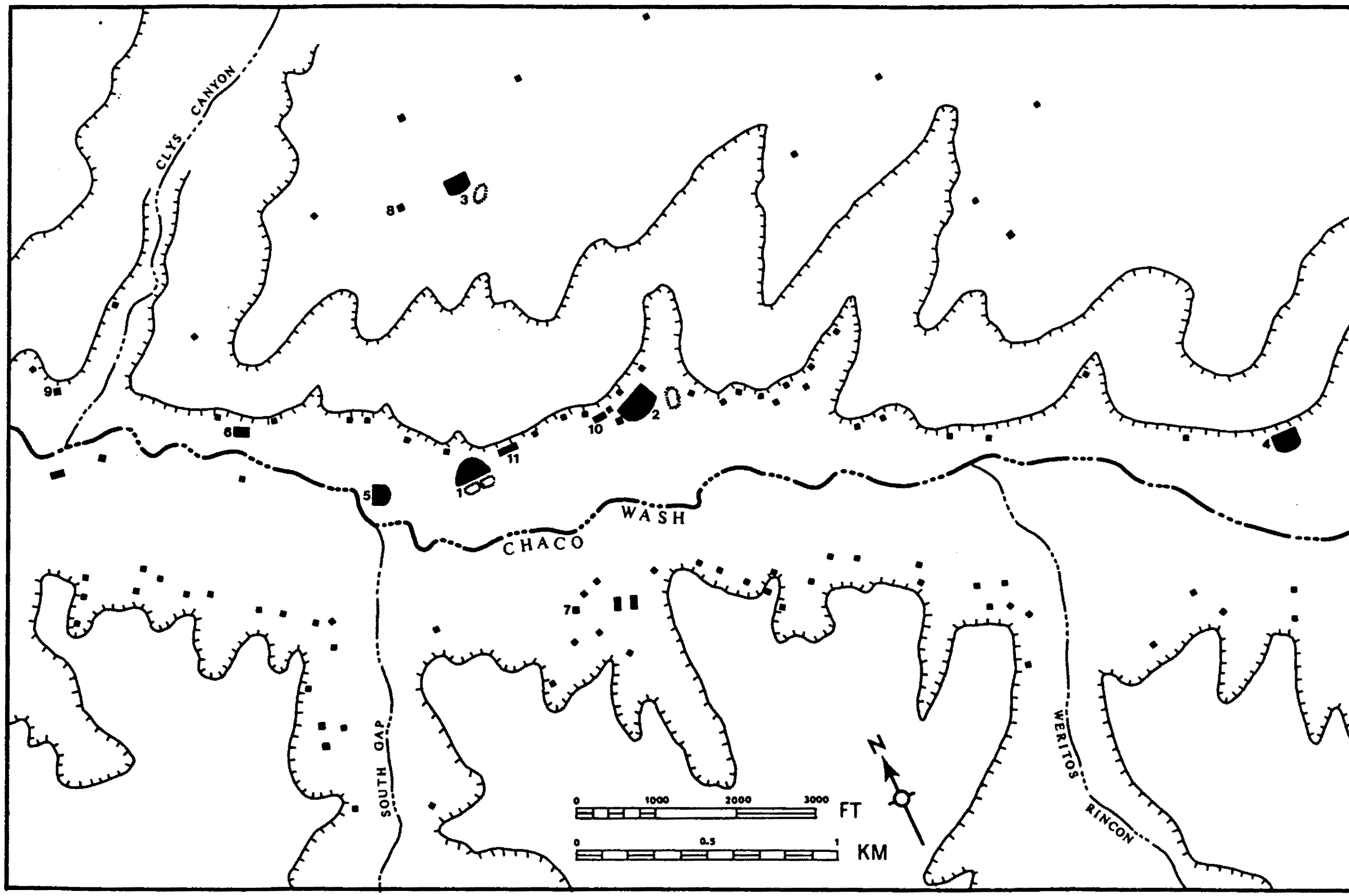

Figure 8. Central Chaco Canyon: 1-Pueblo Bonito, 2-Chetro Ketl, 3-Pueblo Alto, 4-Hungo Pavi, 5-Pueblo del Arroyo, 6-Kin Kletso, 7-Casa Rinconada, 8-New Alto, 9-Casa Chiquita, 10-Talus Unit Number 1, 11-Hillside Ruin, unnumbered squares-small PII/PIII habitations.

sider Pueblo Bonito, Chetro Ketl and Pueblo del Arroyo separately are misguided; these buildings--together with the numerous other structures in the central canyon--should be considered a coherent analytical settlement unit. It becomes necessary to shift our concern from "towns" and "villages" to the canyon itself--especially the central area around South Gap--as a larger settlement of significant complexity. It would not be unreasonable to see this complexity, when coupled with Chaco's regional centrality and relatively high population density, as nearly urban. By the middle 1100s, Chaco was much closer to being a city than simply a canyon full of independent agricultural towns and villages.

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A NEW LOOK AT POPULATION IN CHACO CANYON

Thomas Windes

Abstract

Judge and others (1981) have proposed that the Early Bonito Phase was characterized by a system of resource pooling stimulated by responses to an increasing population and an uncertain environment. For the Classic Bonito Phase (in the late A.D. 1100s), attempts have been made to model an increasingly formalized redistribution system based upon the assumption of an increased permanent population in Chaco Canyon. Clearly the system became more formal and polarized through time as evident by extensive remodeling in the towns, new town construction, increased craft specialization, the development of complex water control systems, and the formation of an extensive network of roads and shrines that mark the direction taken by the system. However, many models of the Classic Bonito Phase imply or point to an increased permanent population in the canyon as being a critical factor in this development. Whether one views an increasing population as being the causal factor for the increasing complexity of the system or whether it is seen as a result of this complexity is not at issue here. The point is that archaeologists have not critically examined all of the data in order to arrive at alternative estimates of the prehistoric population. Data derived from excavations at three towns are examined to evaluate the current suggestion of a large, permanent, town population residing in Chaco Canyon.

Introduction

Chaco Canyon has drawn archaeologists for nearly a century to the large, multistoried houses, or towns, and the literally hundreds of smaller sites, or villages, nearby. The number of rooms represented by this mass of sites in a relatively small area is truly astounding and has provoked images of a large population inhabiting what today is one of the most desolate places in the San Juan Basin. Thus, the effects of demographic causality upon events in Chaco Canyon has always been of concern to investigators of the Chacoan phenomenon (Hawley 1934; Vivian 1970; Judge 1979; Irwin-Williams 1980; Judge and others 1981; Gillespie and Powers 1983). Generally, increasing population has been modeled as a major factor in forcing systemic change. Recent estimates of this population at its peak near the end of the eleventh century have ranged between 4400 and 6000 persons (Pierson 1949; Drager 1976; Hayes 1981), which I believe most archaeologists would accept as reasonable. A population of this magnitude must have imposed serious constraints upon available resources, for instance, denuding the area of wood needed for construction and fuel (Samuels and Betancourt 1982).

Archaeologists have sought to theoretically allay the problem of an expanding population by modeling systemic change or adaptation through an increasingly complex series of buffering mechanisms, such as pooling or exchange of resources (Judge 1979; Irwin-Williams 1980; Judge and others 1981). This would have evened out differential resource availability and the effects of fluctuating precipitation.

But what of the basic assumptions that underlie predictions of an increasingly large population? It has been tacitly assumed by almost all that Chaco Canyon was permanently inhabited for centuries. The large towns comprise about 50% of all population estimates (primarily because of their size and room totals) and a popular view is of tenements packed with urbanites.

The quest of this paper, then, is to review and to offer alternative views to the traditional basic assumptions of permanency and packing of the towns by employing data primarily from Pueblo Alto (Windes 1980), Pueblo Bonito (Judd 1964), and Pueblo del Arroyo (Judd 1959), three of the eight large classic canyon towns. It is not my intent to slight village occupation, but here it is used as a baseline of "normality" to compare with the towns, even though there is tentative evidence that suggests the villages themselves might deviate from permanent extended occupation (Truell 1982).

Previous Chacoan archaeologists have generated the town populations from a variety of techniques but have focused primarily upon room numbers or space as correlates of a permanent resident population. All have assumed that the town spatial organization is duplicated by their historic predecessors, i.e., the towns are simply scaled-up villages. While this may be true, it must be viewed with caution given the uniqueness of the Chacoan phenomenon in Anasazi history.

The Identification Of Households

How might we examine town occupancy and avoid previous and perhaps invalid assumptions? There are probably several ways to do this, but the quality and quantity of the available data force a simplistic approach. The household or commensal unit has often been cited as the smallest integer of a population, and this can be identified by that most essential of features, the room firepit (Chang 1958:298; Turner and Lofgren 1966:129; Dean 1969:76, 143; Ciolek-Torrello and Reid 1974:40; Biella and Chapman 1979:12). Surely, the firepit is nearly a universal necessity for permanent occupation, and the literature abounds with such evidence. There is no reason to suspect that this pattern is atypical in Chacoan towns and villages, and its requisite presence is further noted for historic Puebloan households as well (Mindeleff 1891:109-110; Stevenson 1904:292-293; Adams 1983:49). Its presence and location have also been inferred as an indicator of seasonality (Biella 1979:114-115; Acklen and others 1982:281). Other features may have nearly equal importance in the household, but lack clarity in the archaeological record. Absence of a firepit suggests serious reduction or lack of several important household activities such as heating, cooking, and lighting. Furthermore, its use in the Southwest as an index of population is not rare (Dean 1969:76, 143; Hill 1970:76; Ciolek-Torrello 1978:147-151), although its use in several rooms of a single household can, of course, inflate figures. The possibility of inflated figures is aptly illustrated by Mindeleff (1891:103), who found that the Hopi moved seasonally from upper-story living rooms to ground-story rooms to conserve energy.

Nevertheless, the room firepit appears to be a useful correlate of population and, to simplify matters here, I am going to equate firepit rooms with single households, keeping in mind that the frequency of households may be inflated. Indoor firepits seem a necessity for cold weather and therefore permanent occupation in Chaco. The mean low temperature for December and January over the past several decades has been 12°F (-11°C), with lows of -39°F (-39°C) (William Gillespie, personal communication).

By using firepits as household indicators the following possibilities are expected: (1) If room firepits in towns do not differ in size (and presumed function) and in location from those in villages, then it is presumed that households in both site types are similar. If true, then if the number of room firepits in towns, relative to all rooms (or room area), is similar or greater than in villages, it is plausible that the towns are simply scaled-up villages. Current population estimates are then considered reasonable. However, if the number of room firepits in towns, relative to all rooms (or room area), is less than in villages, then a population less than prior estimates is probable. (2) If room firepit types between towns and villages differ significantly, then alternatives to normal (e.g., village) household patterns must be sought. For example, Stephen Lekson (personal communication) suggests that town kivas might replace certain room functions, thereby reducing their identification in the archaeological room record. If this were true then we might expect the additional activities to be reflected in a greater number and variety of features in kivas similar to earlier pithouse occupation.

Hearth Types And Attributes

First, a brief discussion of "firepits" (i.e., burned pits) is needed since all are not applicable to the present study. There is a wide range of types that I prefer to group under the general category of "hearths." Hearth attributes suggest a variety of functional differences. To examine this, room hearths from three towns and seven contemporary canyon villages were analyzed and classified into three categories on the basis of construction, size, fill contents, and degree of oxidation.

Heating Pits

Small volume, unlined, and poorly oxidized pits scooped into the floor are here termed "heating pits." They usually reflect little or singular use of short thermal duration. Brush and twigs that are seldom burned to ash constitute the primary fuel. Seeds and pollen in the fill typically are sparse, and of little diversity and economic value. These pits have a long history of ancillary use with pithouse firepits (Bullard 1962:163-165). In our case, they are always smaller than any associated firepit, having a mean construction volume of 18.9 liters in villages (n=18, s.d.=14.1). Those at Pueblo del Arroyo and Pueblo Bonito are often difficult to discern based on the available data, and I suspect that most went unrecorded. In contrast, they are numerous at Pueblo Alto, but much smaller (n=100, x=4.0 liters, s.d.=5.8) than our village sample. Everything about heating pits suggests a limited function, perhaps for warming or heating things while the firepit is in use. For example, one next to a set of mealing bins in Pueblo del Arroyo was thought by a Zuni workman to be for warming the grinders (Judd 1959:28).

Firepits

Hearths with large volumes, constructed of adobe or slabs, intensely burned with fuel reduced to ash, and often containing economic pollen and seeds in the fill appear typical of household firepits. They are termed "firepits" here and can be expected to fulfill a variety of functions necessary to the household. Those from our village sample (n=50) yielded a mean construction volume of 44.7 liters (s.d.=20.6). There is some overlap in volume (my criterion for size) between the two types, but other attributes (primarily in construction and oxidation) serve to separate the vast majority. Those at del Arroyo (n=17, x=38.2 liters, s.d.=29.9) and Bonito (n=43, x=44.8 liters, s.d.=27.7) are similar although the quality of the data is poor and less reliable. The firepits from Alto were too few for an adequate sample.

Ovens

A third hearth type, or "oven," is absent in the village rooms and rare in small sites. Its great size, usually in 100s of liters, makes me suspect that having one in your living room would be discomforting, if not downright dangerous as a fire hazard and a cause of anoxia. Very high temperatures appear to have been reached in the ovens, which would seem to be detrimental to normal household cooking, heating, and lighting. Often they are masonry-lined although some are slab-lined or even unlined. A special function is suggested for ovens. Those I know of in the Chaco vicinity are all found in twelfth century contexts.

Hearth Locations At Towns

Pueblo Bonito (Figure 1) offers the best source of town data because it is the most thoroughly excavated. Approximately 90% of the ground-floor rooms have been excavated in the 651-room site (Judd 1964:22). However, there are some distressing problems with the Bonito data, particularly the quantity and quality, which are often less than desirable. More serious to our problem is the multistory construction. Everyone, it seems, has opted for upper-story habitation in the towns, despite the lack of evidence for such a pattern. Proponents of this interpretation, including Judd (see also Lekson and Judge 1978; Adams 1983), feel that the evidence is destroyed by collapse of the upper-story floors. While I concede that this nagging problem will be with us until further excavation occurs, there are some reasons for questioning these views: (1) If upper-story habitation had been widespread, then investigators should have sooner or later stumbled upon its evidence in spite of their excavation techniques. Certainly the problem did not escape Judd (1964:31), who noted the paucity of firepits at Bonito. Work in multistory units at Grasshopper, for example, has indicated little difficulty in identifying nonportable features, such as firepits and mealing bins, after their collapse with roof tops and upper floors (Ciolek-Torrello 1978:155). Remains of upper-story hearths are also relatively common in the fill of excavated Rio Grande pueblos (i.e., Stubbs and Stallings 1953:31; Thomas Windes, personal observation). (2) Residential preference for

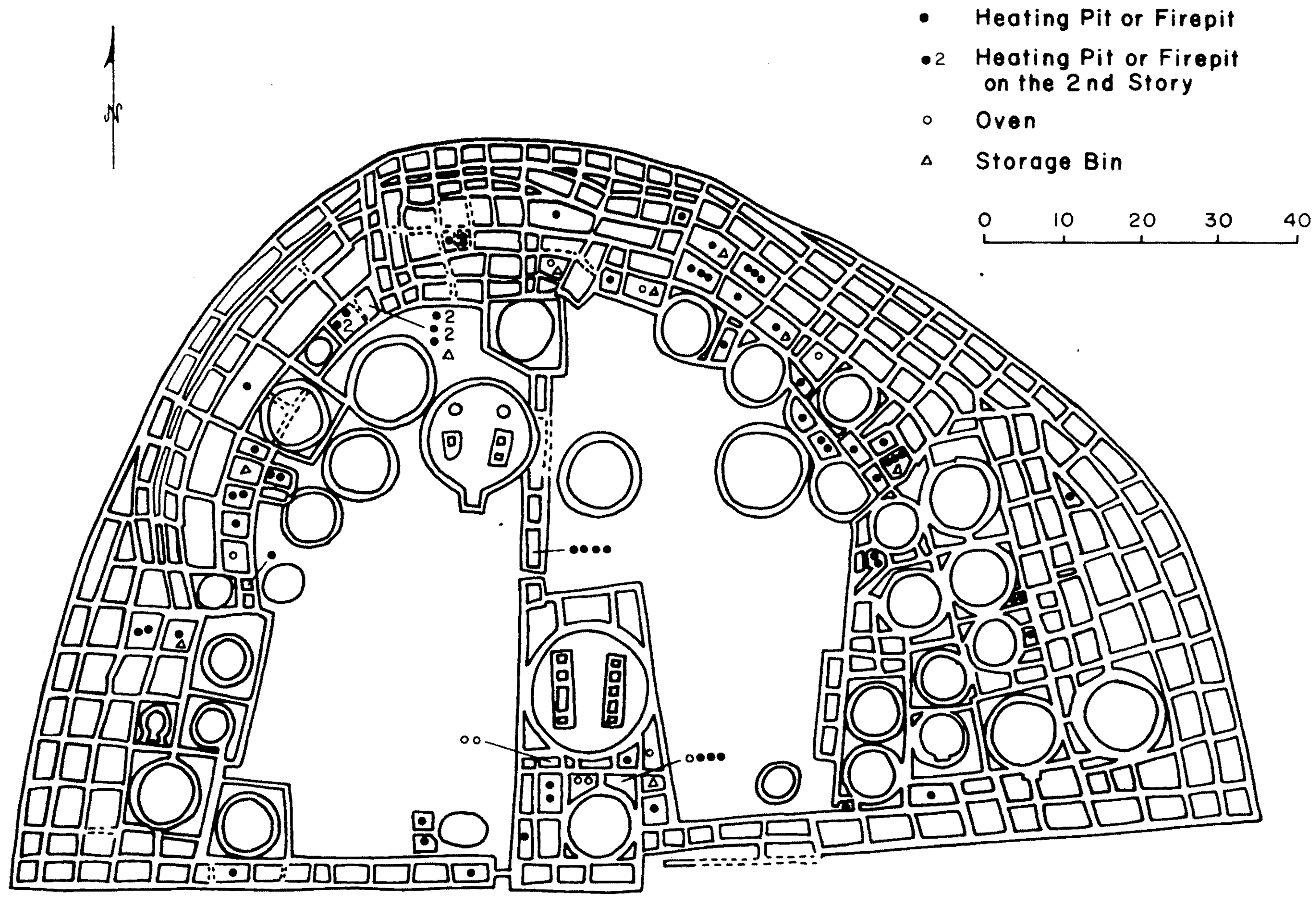

Figure 1. Pueblo Bonito. The location of hearths and storage bins in rooms.

ground-story rooms with direct access to the plaza is not significantly altered between early tenth century Bonito and a small sample of contemporaneous villages excavated by the Chaco Center when the variables of hearth-room position (plaza-facing versus nonplaza-facing single story) are tested against the null hypothesis (n=33, X_c^2=.01, df=1, p=.92). While a trend is more difficult to follow in later period village sites, there again appears to be no significant difference (n=66, X_c^2=1.8, df=1, p=.18). These results lend some credence to the idea that ground-story, plaza-facing habitation is maintained as a cultural norm despite multistory construction.

Furthermore, there is apparently little aversion to using ground-floor firepits in multistory rooms in the towns; 35% (18 of 52) of those at Bonito, and 31% (5 of 16) at del Arroyo are so situated (Figures 1 and 2). The majority of the remainder in both sites were in single-story rooms (60%; 41 of 68). Excavations at Una Vida, another canyon town, also indicate firepit rooms below upper stories and in single stories that originally bordered the plaza (Akins and Gillespie 1979). Finally, at Salmon Ruin, a town 70 km to the north, the Chacoan living rooms remained single story and plaza facing despite the addition of upper stories behind them (Adams 1980: 276-277, 289; Cynthia Irwin-Williams, personal communication). Again this does not prove that there was only lower-story occupation, but it is suggestive that town residential locations may not have differed from contemporary village patterns.

It would be useful to find other features that correlate with hearths or living rooms, but few features were recorded in earlier excavations. One feature that does, the storage bin (not built into walls), reveals a high association with hearth rooms at Bonito, del Arroyo and Una Vida (79%; 11 of 14 with two others in adjacent door-connected rooms). None were found in the Alto rooms. However, it is wall storage niches that are not disturbed by collapsing floors. At Alto all potential living rooms that were excavated yielded multiple storage niches (none occurred in non-hearth rooms), and three of five firepit rooms at Una Vida had them. All the large habitation rooms at Salmon Ruin had large wall niches and a "prolific number of hearths" (Adams 1980:276-277).

Most wall niches at Bonito (73% of 60) and del Arroyo (68% of 20) occur in ground-story rooms although just 16 of the 59 occur in rooms with hearths. Many niches at Bonito (38) and del Arroyo (17) were formed from blocked doors and ventilators that occur primarily in rooms built near the end of the occupation and in ground-story rooms. Of these, only three (at del Arroyo) occurred in rooms with hearths. Although patterns are not clear, it appears that niches are generally ground-story features and that some types may correlate with hearth presence. Unfortunately, many niches probably escaped detection during excavation and may have been obscured later when the walls were stabilized.

Population And Households

If upper-story habitation is minimized at Pueblo Bonito, then approximately 45 households were present for the 200-year Chacoan occupation. The count should be higher, of course, for rooms were rebuilt or torn down, but even doubling the number of households is a far cry from the hundreds predicted for the peak population by others.

It is helpful here to subdivide the occupation at Bonito by major construction periods in order to examine change in household frequency, although it forces acceptance of coeval hearth and room construction with a few exceptions (hearths may be late additions to Rooms 71, 323 and 324).

The earliest construction period at Bonito, A.D. 920-925, yielded 17 rooms with hearths. Two of the rooms have hearths in the oven-size category and are dropped from consideration, leaving 15 households. Perhaps 4 to 10 more are hidden by later construction. All the early, small plaza-facing rooms fronting the huge 40 m^2 storage rooms were probably occupied and formed the basis of at least five households along the west wing. These appear to duplicate the village pattern as suggested by Lekson (Lekson and others 1981). Household suites are less clear elsewhere except for a cluster in the northeast area. Most of the living rooms/households (73%; 11 of 15) in this period were originally next to the plaza, a pattern duplicated in contemporary village sites.

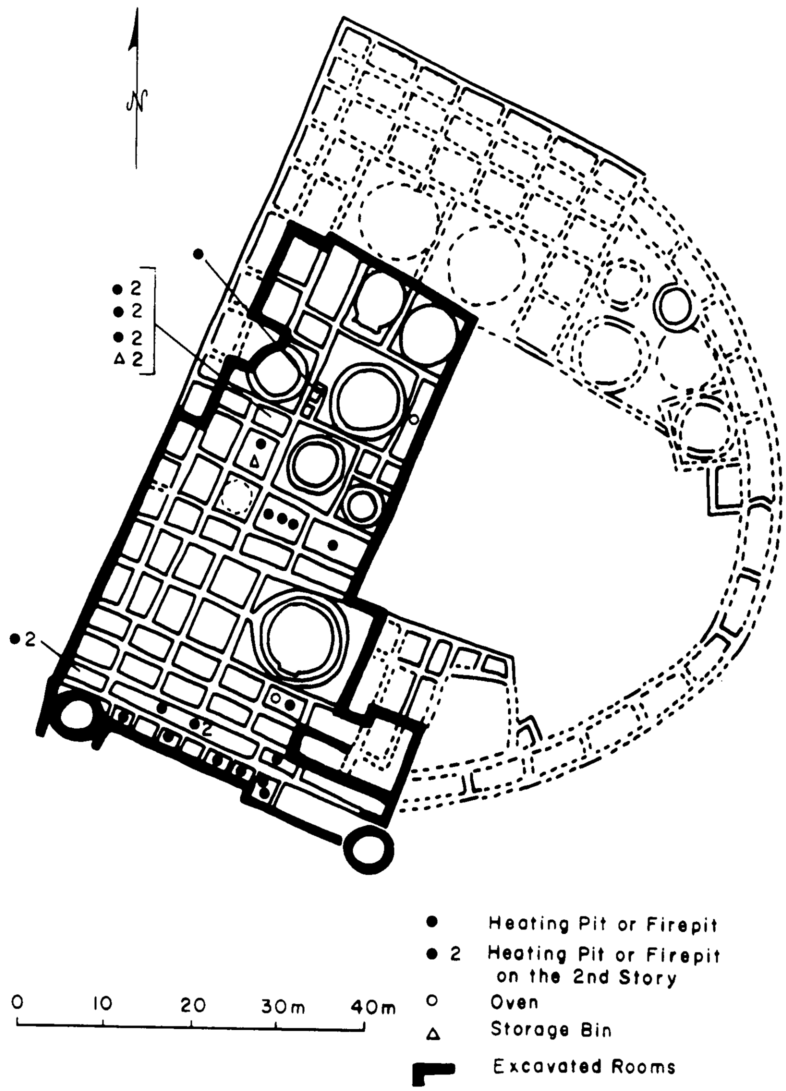

Figure 2. Pueblo del Arroyo. The location of hearths and storage bins in rooms. The area excavated is enclosed by a heavy black line.

The four additional construction periods at Bonito (A.D. 1040-1075/1080) suggested by Lekson (Lekson and others 1981) yielded just 10 potential households. This is a period of much building in Chaco Canyon, and is often considered the height of the Bonito Phase. I am unsure if any earlier household rooms continued into this period; most were abandoned and filled with trash and burials or built over. In the northeast area two old rooms have the look of intensive use and suggest continued occupation until they burned at about A.D. 1100. Nevertheless, the frequency of households is far lower than in the preceding period, unless the original 15 households are prorated into equal 40-year increments (for A.D. 920-1040). If households came and went at a steady rate, then we might have just 5 to 8 households between A.D. 920 and 1040 with the increase to 10 households between A.D. 1040 and 1080.

It is the two or three periods encompassing A.D. 1085-1110 at Bonito that suggest a dramatic rise in population as Lekson (this volume) suggests. A total of 25 potential households were noted. I would expect the presence of these to be the most accurately recorded because little subsequent remodeling took place at Bonito that might have eliminated them from the archaeological record. Because of size and location within confined spaces next to kivas, areas that were unlikely to have been habitation rooms, 7 of the 25 hearth rooms were dropped, leaving 18 households. Most of the rooms eliminated were connected directly to firepit rooms that were part of households already tallied. In comparsion, Hayes' (1981) calculations, based on room numbers, would have yielded 179 households for this final period. Thus, it appears that the household frequency at Bonito might have been far lower than that calculated simply from total room numbers (see Adams 1983:52).

The data from del Arroyo (Figure 2) differ from Bonito in time and quantity. Pueblo del Arroyo was constructed more than a century after Bonito first showed life and only about a third of it was excavated (Judd 1959:6). Its earliest construction period (A.D. 1065-1075) yielded just two hearth rooms, which are adjacent to one another. Others may be buried by later construction. If the pattern is repeated here as elsewhere, then all the plaza-fronting, first-story rooms in this period probably were residential--a total of about six. The late Classic period at Bonito (A.D. 1085-1110) is here represented by six hearth rooms with most occurring during the next, and last, period (A.D. 1110- 1135), a total of nine hearth rooms. At least two in the last two periods, however, are oven-size and should be dropped from consideration.

The last period at Pueblo del Arroyo is biased by seven small rooms appended along the south of the main room block. These contain five of the seven potential households excavated and the other two households may be related to this group. The small size of the rooms and type of construction make them similar to village rooms. Other clusters apparently are appended to the plaza enclosing arc, like those at Alto. I suspect a large number of additional hearth rooms exist among these. As at Bonito, the largest number of households might have been at the end of the site occupation with a small original group still inhabiting the initial building. Again, a smaller residential population is envisoned than one derived strictly from overall room counts.

The data from Alto (Figure 3) allow a more discriminating appraisal than was possible for both Bonito and del Arroyo. In addition, we are unencumbered by multistory problems since, much to our delight, Alto is a single-story building. However, only a small sample of rooms was excavated at Alto, 12% (11 of 89) of the primary rooms in the main room block and none in the tiny rooms of the later additions. The latter rooms probably postdate A.D. 1100 and the primary occupation. Room sampling was structured to examine door-connected suites and not as a random process. The problem is projecting our findings and interpretations to the site level.

Four of the 11 excavated rooms at Alto are potential residences. The two eleventh and twelth century rooms in the central room block are unlike those in the West Wing in size, shape, and intensity of use. One from the central room block (Room 143), facing the plaza, is a long, meter-wide corridor room backed by a suite of empty rooms including two 40 m^2 in size, and is similar to those found in early Pueblo Bonito and other A.D. 900s towns. A sequence of eleventh century floors in Room 143 reveals a fluctuating pattern of intense use (with firepits present) separated by periods of little use (no firepits and few other pit

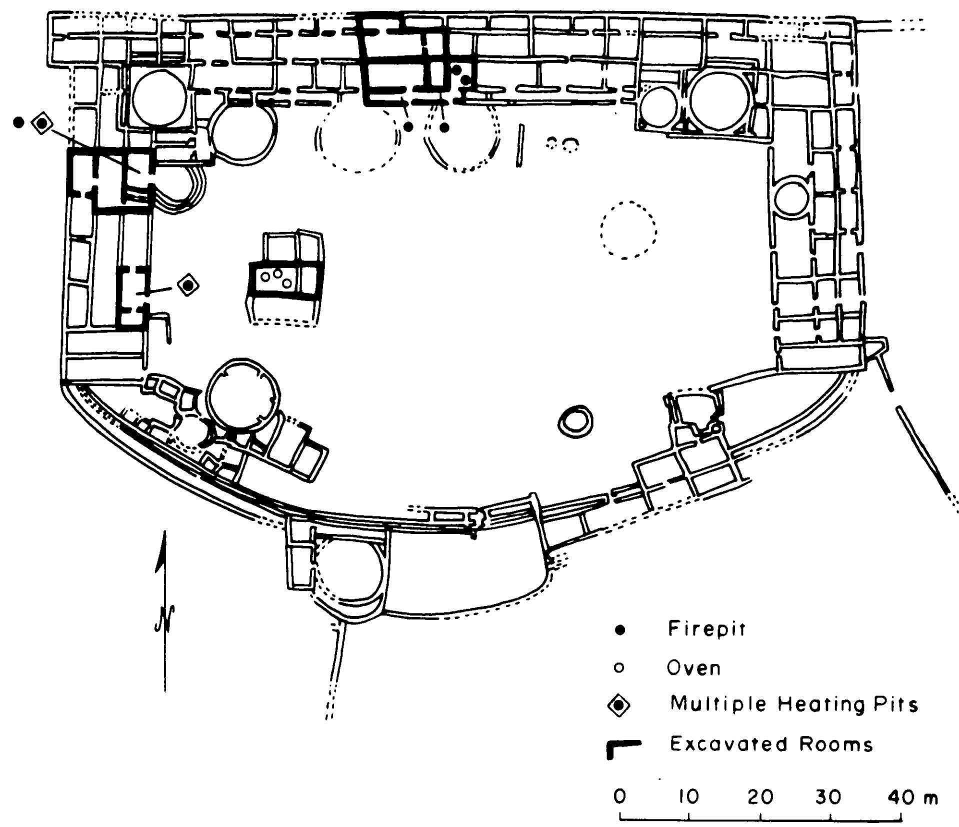

Figure 3. Pueblo Alto. The location of hearths in rooms. Areas excavated are enclosed by a heavy black line.

types present).

Adjacent to the corridor room is another hearth room (Room 147) with access across an elevated end of the corridor room and out onto a large court kiva. In this room the walls had paintings, whitewashings, and multiple plasterings--like the corridor room. There is a well-plastered niche opposite the plaza door, which is unlike others excavated at Alto, except for those in kivas. Two well-oxidized firepits are present. Although excavation did not extend below the first floor, other evidence indicates this room is of late construction. A special, nonresidential use seems probable since this room connects directly by doors to a large plaza kiva.

In the West Wing, two large, plaza-facing rooms have nearly all the earmarks of habitation rooms. Hearths, storage and other pits, mealing bins, and wall niches abound. The floors are badly worn from use. The primary occupation of these was in the mid to late A.D. 1000s. The intense use of the rooms is truly astounding and unmatched by anything reported for other canyon towns, although photos of Rooms 42, 62, and 65 at Pueblo Bonito (Pepper 1920) indicate others did exist. Thus it is of some surprise that firepits are relatively rare in the two rooms, although heating pits abound. One room (Room 103) with five floors has no firepit at all, while the other, also with five floors and much replastering, had a total of just four firepits for three floors. The latter room (Room 110) begins with a floor devoid of features (probably used during construction), which is replaced by one with two firepits but little else. This is followed by one with almost 100 features and much replastering, but it lacks a firepit. There are 29 heating pits; however, all have small volumes except for one of 41 liters, which could have functioned as a temporary firepit. The last two floors show a reduction in numbers of all pits, including heating pits, but two firepits are again present. A kiva later sealed the room.

Could the heating pits at Alto have replaced firepits in function and duration of use? Probably not. At Alto some do share attributes common to firepits: highly oxidized, fuel burned to ash, economic seeds present, and plaster lined. However, their size generally is so small as to be minimally useful for most functions attributable to domestic firepits. The 24 in Room 103 average just 2.8 liters in volume (s.d.=2.0) while the 40 in Room 110 are just 3.5 liters (s.d.=6.7). For all Alto rooms, heating pits average 3.9 liters (n=100, s.d.=5.8). Large ones could have served as firepits, although generally they suggest a short, impermanent use.

If we extrapolate from these three potential households in Rooms 103, 110, and 143 to the whole site, then Alto conceivably could have contained about 20 households in the late A.D. 1000s. For various reasons this figure may be too high--it certainly is a maximum--and half may be more reasonable. We know little of the last occupation (post-A.D. 1100) at Alto as far as households go, although trash from it seems plentiful. However, there does seem to be a shift in occupational characteristics after A.D. 1100 (Windes 1980; Toll and McKenna 1983). Many of the small appended rooms, like those noted for Pueblo del Arroyo, appear to reflect a return to village-type organization.

It is tempting to suggest that the lack of firepits indicates, at times, a nonpermanent occupation. The expedient nature of the heating pits, exhibiting little labor investment, suggests an impermanent use and would have been unsuitable for long, cold-weather occupancy. A shifting pattern of occupant duration (i.e., not long-term) is suspected, at least for the three Alto households excavated. The trash mound stratigraphy at Pueblo Alto (and Pueblo Bonito) also independently suggests seasonal deposition in the late A.D. 1000s, which may reflect intermittent occupation (Windes 1981). Intense town occupation seems to be indicated at times, but for a season and duration that often did not require interior firepits. At this point in time, few plaza firepits that might mark seasonal outdoor use (relative to their frequency in village sites) are known for towns, aside from a number of ovens that appear near the end of town occupation. It is logical to assume that interior firepits would be present if folks consistently wintered in Chaco Canyon.

What of the predicted populations for the three towns in question here--Alto, del Arroyo, and Bonito? If a high index of six persons per household is used, then Bonito might have contained roughly 100 people at its height--in startling contrast to the 1200 suggested by Pierson's (1949) calculations, 1100 by Judd's (1959, 1964), 800 by Hayes' (1981) and 500 by Drager's (1976). The revised figure is more in line with the burial figures given by Akins and Schelberg (this volume) for Bonito. About 40 to 60 people are predicted for del Arroyo in contrast to figures of 263, 285 and 475 calculated by Drager, Hayes, and Judd, respectively. At Alto, a high of about 100 and low of about 50 is indicated as contrasted to 400 by Pierson, 320 by Drager, and 130 by Hayes. The revised figure is not unreasonable if the primary role for the Alto residents was to supervise local and regional road traffic (Windes 1982b). Furthermore, the estimated amount of charcoal in the Alto trash mound is so low as to preclude a large permanent population (Windes 1981). Extrapolating these low figures to other towns, of course, would generate a considerably smaller canyon population assuming occupation is contemporary and not above normal in the villages. There is tentative data to suggest that the village population is also smaller than predicted by others (Windes 1982a).

Conclusions

In summary, a different perspective of town occupation is offered, one that suggests a relatively low population existed in towns and was, perhaps, at times intermittent or seasonal. Lekson's study of town architecture suggests that population figures are similar to those inferred here in amplitude but not in magnitude (Lekson this volume). That is, population reaches its peak near the end of town occupation but we disagree on its size. Of course, the question of upper-story residency in most towns will continue to be debated, and if verified would change these calculations accordingly. However, a continuity of single-story, plaza-facing residence patterns between villages and towns seems plausible, and evidence from Pueblo Alto and the Salmon Ruin does not contradict this pattern. The noticeable difference between village and town is in the amount of nondomestic space relative to living room space. This suggests that towns are not simply scaled-up villages inhabited by multitudes but are occupied by small numbers of elite with differential access to resources and power--a probability offered by other lines of evidence (e.g., Akins and Schelberg this volume). A greatly reduced population in the canyon, perhaps 2000 or less in the late A.D. 1000s, will affect recent models that rely upon stresses induced by a large permanent population.

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EVIDENCE FOR ORGANIZATIONAL COMPLEXITY AS SEEN FROM THE MORTUARY PRACTICES AT CHACO CANYON

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Abstract

An analysis of mortuary practices is one of the most useful means by which to address questions concerning social complexity. Human burials have been excavated at Chaco Canyon from the late 1890s to the present. The quality of information that has survived differs greatly. Less than one-third of the known burials have sufficient information concerning the burial circumstances and associated grave goods to be used in an analysis of mortuary practices. There is considerable variation in the kinds and amounts of grave goods and this analysis has been directed towards isolating the factors contributing to this distribution. Items that can be considered status markers are consistently found with great house burials suggesting that the ranking of individuals within the society was ascribed rather than achieved. Evidence of two ranking lineages can be seen at Pueblo Bonito.

Introduction

One of the long-range goals of anthropology is to increase our ability to monitor and explain variation and change in the societies we study. This can best be accomplished by decreasing our reliance on arguments of direct analogy and by considering the conditions under which we would expect certain responses. Propositions concerning social complexity can be tested by using a burial population. Cross-cultural studies of ethnographically recorded mortuary practices have demonstrated that the structure and organization of social systems and the status positions of the members of the society are symbolized at death (Saxe 1970; Binford 1971).

Saxe (1970) has pointed out that an underlying thread of commonality among the social evolutionary theorists is their emphasis on the qualitative difference in the kinds of integrative problems encountered in systems of differing complexity. There is a qualitative difference in the nature of such integrative mechanisms adopted by societies at different levels of complexity.

The two levels of complexity with which we will be concerned are the ranked and the stratified. Ranking exists when there are fewer status positions than persons capable of filling them. The result is criteria other than those of age, sex, or personal attributes limit access to status positions. Rank has no necessary connection with economic status; however, some will exist. Stratified societies are more complex and exist in situations where the status difference is based on economic differences such that certain adult members of society enjoy differential rights of access to basic resources (Fried 1967).

The grave offerings for all members of a ranked society are relatively similar in the range and type of materials; the quantity of items will increase as the age increases, and there will be a tendency for activity-specific goods to be associated with males and females. Utilitarian artifacts predominate. Status markers are few in number both in the entire population and with any individual. Most of the offerings represent items that were personal in nature, of low value to the society and of little cost to the group. However, there will be some status markers with economic underpinning that override the dimensions of age, sex, and societal affiliations. Because any one individual could belong to a number of sodalities, representations of many of these could figure into the act of interment. There may be sodality-based corporate burial practices (Saxe 1970; J. Brown, personal communication; Brown 1982).

By contrast, a stratified society is characterized by more dimensions of funerary remains that are applicable to fewer and fewer individuals. There is a greater range in the quality and quantity of offerings between the superordinate and subordinate members of society, and there will be dissimilarities in their mortuary treatment. The corporate involvement will be greater for the superordinate. There should be a central burial facility for members of the ranking lineage, and the range of exotic goods functions to legitimize and emphasize the positions of the superordinates in the society. The ranking is hereditary; therefore, burials of infants and children would contain status markers (Saxe 1970; J. Brown, personal communication; Brown 1982).

It has been noted that the subordinate dimension within a stratified system will appear egalitarian in their organizational characteristics (Black 1979; Goldstein 1980). That is, while some persons are accorded higher status, it is on the basis of personal achievements and therefore related to the age and sex of the individual. This is particularly pertinent to Chaco. If the burials from a single village site or even all of the village sites are treated as a population, they would more closely resemble a ranked or an egalitarian system. But when the range is extended to include the great house sites, there is definite evidence of a stratified system. Since we have no reason to believe that the villages and great houses did not operate as one system, the burials must be treated as a single population. This discussion will be aimed toward a demonstration that the data do support the existence of a stratified society.

Mortuary Practices In Stratified Societies

Peebles and Kus (1977) suggest five archaeological correlates of chiefdoms or stratified societies. One of these is concerned with burial practices (1977: 431):

> There should be clear evidence of nonvolitional, ascribed ranking of persons. The most effective way to demonstrate such ranking is through the analysis of mortuary practices.

In addition to the previously mentioned characteristics, Peebles and Kus (1977) indicate that the superordinate dimension must exhibit energy expenditure not solely ordered on the basis of age and sex. Membership reflects "the ascriptive qualities of an individual's genealogy"; therefore, the only category that will contain only adults is the paramount. The subordinate dimension will feature energy expenditure generally ordered on the basis of age and sex. "The older an individual, the greater his opportunity for accomplishment, and the higher his rank." Adult burials should have greater energy expenditure than children, who will, in turn, have more than infants. "In general, symbols of rank and office of the superordinate dimension will not be found in the subordinate dimension." The energy expended on the lowest ranking individual of the superordinate dimension will be greater than that spent on the highest ranking member of the subordinate. Finally the number of burials in the superordinate dimension should "decrease markedly" with each increase in rank, whereas the subordinate burials should reflect the structure of the population (Peebles and Kus 1977:431).

From these criteria, several test propositions can be derived for the Chacoan burial data. There should be a few paramount burials that will be associated with the great houses and will be found in organized cemeteries. They should be buried with quantities of status materials, some of which are not available to the entire population, and there should be evidence of more than the usual preparation for the interment. Since not only the paramount but his family resided at the great house, burials that are part of the superordinate dimension but not as elaborate as the paramount ones should also be found at the great houses. These should include both males and females as well as children and, as a whole, will be more elaborate in terms of interment ritual and burial goods than those of the village sites or subordinate dimension.

The subordinate dimension should be associated with the village sites and may have evidence of ranking within these burials. Some would have more elaborate funerary preparation and more burial goods, but these will be more reflective of personal achievement than those of the superordinate.

The Chacoan Burials

The remains of four or possibly five paramount burials have been found in Chaco Canyon. These are suggested on the basis of masses of status items found with the bodies, particularly turquoise.

The best documented are those recovered from Pueblo Bonito by Pepper (Pepper 1909). In one room, beneath the disturbed burials of 14 to 16 individuals, a surface made of wooden planks averaging one foot wide and three quarters of an inch in thickness was found. These were laid side by side in an east-west direction forming a floor. Beneath this floor were the burials of two adult males who lay in a bed of wood ashes and yellow sand. The first was extended on his right side with his head to the northeast; the second was semiflexed on his back with his head to the north. Both exhibited chopping and percussion blows to the head, suggesting violent deaths.

The first was associated with 5902 pieces of turquoise (5890 beads, 9 pendants, and 3 inlays) and 3 shell beads. The other had much more: approximately 13,000 turquoise objects (11,036 beads, 728 pendants, 1221 other pieces of turquoise), 5 jet inlays, 94 shell bracelets and 15 fragments, 3326 shell beads, at least 5 other shell ornaments, a shell trumpet, bivalve shells, and stone beads. Other objects were described as being nearby but not directly associated with him. Offerings of turquoise, shell, and stone were found in the four corners of the room while quantities of turquoise objects including two tadpoles, five frogs, and seven buttons were described as coming from the "general debris surrounding the skeletons."

The other possible paramount burials are not well documented. Another instance, also from Pueblo Bonito, was recounted to Gordon Vivian by Mrs. Richard Wetherill. She told of a large square room on the west side of the pueblo, where in the center of the room was the extended burial of a man with strands of turquoise beads wrapped around his forehead, looped around his shoulders and hung down to his waist. She recalled that there was almost a bushel of turquoise on him (Vivian 1948). Around the wall of the room were 13 skeletons of women, none with any ornaments. Judd (1954) gives an account of a Col. D. K. B. Sellers of Albuquerque who, with another man, broke into a large room on the west side of Bonito and found part of the mummified body of a woman and a quantity of turquoise, including two turquoise birds.

Only one possible paramount burial from a site other than Pueblo Bonito has been reported. Pepper refers to one at Penasco Blanco where "masses of turquoise ornaments have been found associated with bodies buried in rooms" (1909: 248). We know little else about this burial other than the excavator was probably a Navajo known as Old Wello who claimed to have been under the employ of Richard Wetherill (Judd 1954:345).

If social stratification were present, we would expect to find not only the vertical differentiation of superordinates and subordinates but also differential treatment within the ranking lineage (horizontal differentiation) (Blakely 1977). The burials from Pueblo Bonito may demonstrate this. Clusters of burial rooms that may represent two "cemetaries" were found within the site. Those investigated by Pepper were located in the northwestern portion of the site and those encountered by Judd were in the west. Discriminant analyses were performed (Akins in preparation) on 18 cranial measurements of the individuals from the two clusters (n=18 and n=21) to determine whether they represented two distinguishable groups. These tests indicate that they do and suggest two "ranking lineages" at that site.

The individual burial rooms from both clusters were examined to determine if there were differences in the nonparamount superordinate dimension that could not be related to chronology. Those with materials felt to be status markers all occurred in associations that date roughly between A.D. 1050 to 1130. Status goods were found associated with burials in Room 326 with the disturbed bodies of five adult females. Rooms 320 and 329 contained a number of disturbed burials, which were mostly female, with some turquoise and shell ornaments. A third room (330), with its mostly male interments and much disturbance, contained turquoise beads and tesserae. Quantitative comparisons are not possible. Neither Judd nor the Smithsonian catalog cards give the number of objects--usually just the presence.

On the other hand, Pepper's disturbed superordinate nonparamount burials were associated with large quantities of status items. The total number of turquoise objects recovered above the floor separating these from the paramount individuals included approximately 25,000 beads, 1052 small worked pieces, 451 sets designed for inlay, and 503 pendants of turquoise. There were 2,042 shell beads, 10 discs of *Haliotis* shells, 98 fragments of shell bracelets, 17 shell pendants, 2 large *Olivella* shell beads, an inlaid shell, and a large bird form. There were also 173 sets of stone, a fragment of a jet ring and an inlay made of iron pyrite. More general objects included fragments of canyon walnuts, pinyon nuts, seeds, fragments of textiles, which probably wrapped the bodies, a quartz crystal, a chipped quartz crystal knife, gypsum, limonite, azurite, mica, six arrow points, turkey gizzard stones, a few fragments of pottery, and some animal bones (Pepper 1909). Not all of the individuals interred in the rooms had equal numbers of status objects. Since the discriminant analyses indicated that the individuals within each cluster were closely related, some differential treatment within the lineages is suggested. In two of these instances, children were found to be associated with status markers.

Unfortunately, many of the infant and child burials were disturbed. Those that were undisturbed generally had at least some pottery. One from Room 329 had two shell pendants and three bowls. Another from Room 330, and not included in the sample analyzed, had a pendant and earrings of turquoise in direct association, and many other materials were found in the room. The most suggestive child burial was partially exhumed by Moorehead (Pepper 1920). In cleaning out Room 53, Pepper found the skull of a child near the east wall, and near it a deposit of over 4,000 flat circular turquoise beads, 30 shell beads or pendants, and other material. If these offerings were indeed associated with the skull, it is our best evidence of hereditary ranking.

The Analysis

If the Chacoan system was a stratified society, we would expect that the great houses, as residences of the elite, would be associated with those items considered to be status markers regardless of the age and sex of the individual. In addition, since the stratification is felt to be connected with the regional exchange system, there should be a change over time with the status markers found predominantly during the time period between A.D. 1000 and 1130 (Red Mesa and Gallup ceramic associations). Utilitarian objects would be expected in all dimensions and would not vary with time. There should be some variation dependent on the age and sex of the individual rather than only on the site type.

In order to test these expectations, 232 of the better documented and undisturbed burials from Chaco Canyon were culled from the literature and archives. Over 650 burials are currently known from the canyon and "Kin Neole." These include 48 from great houses (n=4), 175 from village sites (n=24), and 9 of unknown association. In general these date from A.D. 900 to 1300 with the most (141) falling between A.D. 1050 and 1130. Individuals of all age groups and both sexes are represented.

Ninety-six percent of the great house burials occurred within the structure; whereas in the villages 49% occurred in trash areas. This is not a sampling problem; the many tests of great house trash middens have not revealed burials. There is also a contrast in the room burials. In the Pueblo Bonito burial rooms, the burial placement began on the floors, suggesting that the rooms were closed for that purpose, i.e., at a loss of space to the community and representing a cost to the community. Since this space seemed to have been used for specific lineages, they can be considered to constitute organized cemeteries. In contrast, the room burials from the villages were largely either infant or child subfloor burials or were interments in the trashy fill of abandoned rooms and did not represent a loss of space to the community.

Energy expenditure at the great houses can be seen in the plank floor and yellow sand and ash floor of Pepper's paramount burials. To a lesser extent, Judd felt soil had been brought in to cover many of those he exhumed. There was also a tendency for more organized interment at the great houses. There, during the time when stratification was most evident (Gallup ceramic associated deposits), 76.5% of the burials were extended, 82.3% were on the back, and more often the head was to the east (60.0%). In the villages at the same time these characteristics were quite variable. Sixty-seven percent of the burials were flexed, 41.1% rested on their backs, 24.4% lay on their left side, 24.4% on the face and 20% on the right side. At the villages, an orientation to the east accounted for 41.5% of the sample followed by north, south and west with 19.5% each.

To test whether organized interment was more likely to be found at the great houses, the burial location and three positioning variables were used. All but the orientation were found to be statistically significant at the .05 level. When age and sex were tested against these same variables, the results were not significant, suggesting that the patterning was related to the site type rather than the age or the sex of the individual (Tables 1 and 2).

Ornaments were examined to see if they functioned as "badges of office" or status markers. It was felt that turquoise should exhibit this to a greater degree than ornaments of other materials. The bone and shell recovered from burials were ubiquitous in time and probably did not have an economic importance assigned to them. Bone beads were consistently found at the village sites. While there were more instances and greater quantities of shell at the great houses, it was also present at the villages (Tables 3 and 4).

During the time period in question (A.D. 1050-1130), turquoise beads were almost exclusively associated with burials at the great houses, and then in only 26% of the cases in this sample. By contrast, at the village sites, with a larger sample (107), only one individual (less than 1% of the sample) was interred with turquoise beads. This (Bc 51 60/51) was a female approximately 34 years of age buried in the trash area with a feather robe, cotton cloth, four mats, a basket, a bone flesher, five ceramic vessels, two turquoise beads, and a shell pendant. It probably represents achieved status within the subordinate dimensions.

Six percent of the entire burial sample had associated turquoise beads and all but one of these were adults. The exception was a child from one of the Pueblo Bonito rooms. Males had a slightly greater association with turquoise beads, 16.6% of the males as compared with 11.5% of the females.

In the sample, turquoise pendants were distributed slightly differently. In the time period from around A.D. 1050 to 1100, these were associated with the great houses; however, slightly later, between A.D. 1100 and 1150 (mixed Gallup and Chaco-McElmo ceramic associations), pendants were found in both great houses and villages. These were always associated with adults and equally distributed between males and females.

Shell was not significantly related to the site type, age, or sex of the individual in the Gallup sample. However, there were greater quantities and exclusive forms such as shell trumpets and bivalves found only with the great house burials. Stone ornaments were not related to the site type, age, or sex of the individual, but since this category encompasses a large variety of materials and kinds of objects, this is not surprising.

Utilitarian items would not be expected to be distributed in the same manner as status markers, and they were not. Individuals in all sites were buried with both bowls and pitchers, although adults were more likely to have vessels and had more vessels if they were buried at a great house (Table 5). The only apparent difference was that pitcher forms were more likely to be found with females and children than with males. This suggests that ceramic vessels would fall under the category of personal possessions and would not reflect stratification.

A few groups of mortuary offerings appear to reflect achieved status. Humerus scrapers, usually accompanied by elliptical basket trays, were consistently associated with adult females (six cases). Bone awls, although low in frequency, were more often associated with males (five) than females (two). Projectile points occurred at all site types in all time periods but only with adult burials. Of those where the sex of the individuals was known, three were male and three were female; however, for two of the females the points may have functioned as ornaments.

Conclusions

The findings of this study suggest that the burial population from Chaco Canyon do meet the criteria for a stratified society set forth by Peebles and Kus (1977), as well as Blakely (1977) and Brown (1982). The constant association of status markers with the great house interments suggests higher status for their inhabitants. Within the superordinant dimension there is evidence of a paramount position and possibly of two ranking lineages.

TABLE 1. Organizational features of human burials for all time periods (unknown cases not included).

site type:	great house	village
burial location		
room fill	38	53
room subfloor	7	34
trash	2	82
total	47	169
X^2=40.536 df=2		
flexion		
flexed	7	78
semi-flexed	6	40
extended	19	17
total	32	135
X^2=33.913 df=2		
position		
left	6	33
right	4	21
back	22	46
face	1	28
total	33	128
Xc^2=9.773 df=3		
orientation		
north	4	21
south	3	22
east	18	35
west	7	31
total	32	109
Xc^2=4.792 df=3		

age of the individual:	infant	child	s.adult	adult	o. adult
burial location					
room fill	19	10	7	51	4
room subfloor	13	2	2	23	1
trash	8	21	7	45	5
total	40	33	16	119	10
Xc^2=14.136 df=8					
flexion					
flexed	12	10	6	54	6
semi-flexed	10	6	3	27	2
extended	4	5	2	24	1
total	26	21	11	105	9
Xc^2=1.477 df=8					
position					
left	10	2	5	20	2
right	1	4	0	18	2
back	9	10	5	43	4
face	6	7	0	15	1
total	26	23	10	96	9
Xc^2=11.406 df=12					

TABLE 1 (continued).

age of the individual:	infant	child	s.adult	adult	o. adult
orientation					
north	4	3	0	17	2
south	3	4	1	16	2
east	8	8	5	30	3
west	11	4	2	20	2
total	26	19	8	83	9
Xc^2=4.113 df=12					

sex:	male	female	immature/unknown
burial location			
burial location			
room fill	25	27	31
room subfloor	11	10	17
trash	11	18	35
total	47	55	83
X^2=5.460 df=4			
flexion			
flexed	21	23	25
semi-flexed	11	13	17
extended	7	15	10
total	39	51	52
X^2=2.510 df=4			
position			
left	5	10	16
right	13	4	5
back	17	23	20
face	5	8	13
total	40	45	54
X^2=15.698 df=6			
orientation			
north	8	7	7
south	5	7	8
east	9	23	18
west	13	6	16
total	35	43	49
Xc^2=9.414 df=6			

TABLE 2. Organizational features of human burials during Gallup times (unknown cases not included).

site type:	great house	village
burial location		
room fill	23	11
room subfloor	3	10
trash	1	46
total	27	67
Xc^2=38.257 df=2		
flexion		
flexed	1	38
semi-flexed	3	14
extended	13	5
total	17	57
Xc^2=30.123 df=2		
position		
left	1	11
right	2	9
back	14	14
face	0	11
total	17	45
Xc^2=10.439 df=3		
orientation		
north	1	8
south	2	8
east	9	17
west	3	8
total	15	41
Xc^2=1.040 df=3		

TABLE 3. Distribution of ornaments in human burials for all time periods (unknown cases not included).

site type:	great house	village
bone beads		
absent	49	167
present	0	7
total	49	174
X_c^2=.928 df=1		
turquoise beads		
absent	41	172
present	8	2
total	49	174
X_c^2=17.138 df=1		
turquoise pendants		
absent	42	171
present	7	3
total	49	174
X_c^2=11.280 df=1		
shell ornaments		
absent	42	167
present	7	7
total	49	174
X_c^2=5.197 df=1		
stone ornaments		
absent	45	169
present	4	5
total	49	174
X_c^2=1.559 df=1		

TABLE 4. Distribution of ornaments in human burials during Gallup times only (unknown cases not included).

site type:	great house	village
bone beads		
absent	27	66
present	0	2
total	27	68
Xc^2=.010 df=1		
turquoise beads		
absent	20	67
present	7	1
total	27	68
Xc^2=12.013 df=1		
turquoise pendants		
absent	21	68
present	6	0
total	27	68
Xc^2=12.636 df=1		
shell ornaments		
absent	22	65
present	5	3
total	27	68
Xc^2=3.337 df=1		
stone ornaments		
absent	24	66
present	3	2
total	27	68
Xc^2=1.215 df=1		

age of individual:	infant	child	subadult	adult	old adult
turquoise beads					
absent	13	15	9	47	3
present	0	1	0	7	0
total	13	16	9	54	3
Xc^2=1.619 df=4					
turquoise pendants					
absent	13	16	9	48	3
present	0	0	0	6	0
total	13	16	9	54	3
Xc^2=2.333 df=4					
shell ornaments					
absent	12	14	8	50	3
present	1	2	1	4	0
total	13	16	9	54	3
Xc^2=.525 df=4					
stone ornaments					
absent	13	16	9	49	3
present	0	0	0	5	0
total	13	16	9	54	3
Xc^2=2.016 df=4					

TABLE 4 (continued).

sex of individual:	male	female	immature/unknown
bone ornament			
absent	18	29	32
present	0	0	2
total	18	29	43
Xc^2=.608 df=3			
turquoise beads			
absent	15	26	33
present	3	3	1
total	18	29	34
Xc^2=1.405 df=2			
turquoise pendants			
absent	16	25	34
present	2	4	0
total	18	29	34
Xc^2=2.687 df=2			
shell ornaments			
absent	16	28	30
present	2	1	4
total	18	29	34
Xc^2=.199 df=2			
stone ornaments			
absent	15	27	34
present	3	2	0
total	18	29	34
Xc^2=3.200 df=2			

TABLE 5. Presence and absence of ceramic forms in human burials during Gallup times only (unknown cases not included).

house type	great house	village
bowls		
absent	13	35
present	14	33
total	27	68
X^2=.085 df=1		
pitchers		
absent	16	40
present	11	28
total	27	68
X^2=.002 df=1		

age of individual	infant	child	subadult	adult	old adult
bowls					
absent	7	7	4	28	1
present	6	9	5	26	2
total	13	16	9	54	3
Xc^2=.090 df=4					
pitchers					
absent	7	8	8	33	1
present	6	8	1	21	2
total	13	16	9	54	3
Xc^2=2.510 df=4					

sex of individual	male	female	immature/unknown
bowls			
absent	12	14	16
present	6	15	18
total	18	29	34
X^2=2.043 df=2			
pitchers			
absent	15	15	20
present	3	14	14
total	18	29	34
X^2=4.908 df=2			

While the mortuary data do support the existence of a stratified society, this must be considered along with other evidence. There is a hierarchy of settlement types and sizes (Schelberg this volume). There is evidence of organized construction of the great house sites, which required both planning and a labor force (Lekson this volume). The turquoise workshops suggest part-time craftmanship, and the locations of some of these in village sites suggest interaction between village and great houses (Mathien this volume). The distribution of trachybasalt tempered vessels (Toll this volume) and nonlocal lithic resources (Cameron this volume) suggests differential access to resources.

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DISEASE AND MORTALITY PATTERNS IN THE BURIAL ROOMS OF PUEBLO BONITO: PRELIMINARY CONSIDERATIONS

Ann M. Palkovich

Abstract

Human skeletal remains recovered from several burial rooms in Pueblo Bonito represent the largest series of burials from Chaco Canyon known to date. Paleodemographic reconstruction demonstrates an atypical age distribution for this skeletal series; subadults are notably underrepresented. In addition, several pathologies associated with nutritional stress are prevalent. It is suggested that dietary inadequacies crosscut status distinctions. Apparently all Chacoan groups were affected by the nutritionally marginal agrarian subsistence experienced during the eleventh century A.D.

Introduction

Human skeletal remains recovered from archaeological sites provide biological evidence for the dynamics of prehistoric regional interactions and adaptations. The ramifications of shifts from simple to complex social organizations in light of fluctuating environmental conditions can thus be considered from a biological standpoint. Several regionally based studies have effectively demonstrated that shifts from hunting/gathering strategies utilized by small groups to food production found in larger groups do not necessarily imply an accompanying and equally effective human biological adaptation (Angel 1975; Cook 1976; Buikstra 1977; Mensforth and others 1978). Often, to the contrary, these larger groups experience, for the first time, an increase in (or a development of more severe forms of) demographic and dietary stress as evidenced in morbidity and mortality profiles reconstructable from skeletal data.

The presence of dietary stress has been demonstrated in a number of studies of prehistoric Pueblo populations (Jarcho and others 1965; El-Najjar 1974, 1977; El-Najjar and others 1975, 1976; Von Endt and Ortner 1982) and has been suggested as a widespread phenomenon occurring throughout prehistoric Southwestern Pueblo groups (Palkovich 1982). The patterns of skeletal pathology and mortality profiles are usually shown to represent conditions of nutritional inadequacy among these prehistoric Pueblo societies. From a dietary viewpoint, a shift in group organization frequently will lead to a temporarily successful, though usually still marginal, existence for these groups. However, the relative instability of the environment soon upsets this fragile balance and even the buffering of food resources resulting from changed subsistence strategies (e.g., irrigation farming instead of dry farming) ultimately cannot mitigate the long-term biological decline. From a biological standpoint, then, prehistoric Pueblo dietary adequacy might be characterized as marginal at best with concomitant increases in morbidity and mortality as the quality and quantity of subsistence resources are diminished. Such a characterization would explain the widespread evidence of nutritional stress when documented as individual cases yet it also accounts for temporal and spatial differences in morbidity and mortality patterns noted among prehistoric Pueblo groups.

Given the arguments presented for the development of stratified societies in Chaco Canyon (Schelberg 1982), an examination of the biological success of this organizational strategy is instructive.

Judd's Burial Cluster

Despite the relative paucity of interments recovered and retained from the various excavations conducted at Chaco Canyon, the burials that are available for study do afford some insight into the extent of biological stress experienced by this population. A number of "burial rooms" in Pueblo Bonito have yielded the largest single cemetery series of interments from Chaco Canyon known to date. Serving a secondary function as a mortuary facility, a single room may have originally contained over 30 burials--most were primary, single, individual interments. Some skeletons were badly disturbed and disarticulated (Judd 1964).

Previous descriptions of Chaco burial rooms (Pepper 1909, 1920; Judd 1964) have focused primarily on the artifact assemblages found in association with the interments. Usually skeletal information is only incidentally provided in these reports. Thus, a survey of the existing skeletal collections was conducted (N. Akins, personal communication) to collect basic biological data.

Skeletal remains from Judd's excavations conducted between 1925 and 1928 have been retained as part of the Smithsonian Institution's research collections. Remains from four of these burial rooms--320, 326, 329, and 330--are of particular interest for this study. While some human remains were scattered in several additional rooms according to Judd's excavation records, the greatest concentration of burials he recovered was contained in these four.

These are contiguous rooms located along the western extent of the pueblo. Architectural, stratigraphic, and ceramic analyses (Akins and Schelberg, this volume) as well as Judd's notes (1964) suggest these rooms were purposefully converted into mortuary facilities; bodies were laid on the hardpacked floor, and dirt was then brought in to cover them. Some intrusion upon earlier interments by later ones is evidenced by the numerous disturbed skeletons noted at the time of excavation, although the extent of disturbance could also suggest looting. While it is believed that the majority of the skeletal material was retained from these excavations by Judd, some questions remain about this collection since the completeness of his recovery techniques cannot be established. For example, it is possible that infants may not have been recognized or recovered during excavation--particularly in light of the far greater number of infants Hrdlicka recovered from the cemetery of a small site in the vicinity of Kin Bineola. These burials are stored in the American Museum of Natural History under the designation of Kin Neole, and this designation is used herein.

Based on rough age estimations from examination of these burials and field notes when the burials themselves were unavailable (N. Akins, personal communication), it is possible to compare the general age profile of the entire documented skeletal series recovered from all excavations at Pueblo Bonito to several smaller contemporaneous occupations at Chaco Canyon. These include BC 51, BC 53, BC 59 and Kin Neole (Table 1). Pottery associations of Late Red Mesa and Gallup/Chaco-McElmo types date all of these sites between A.D. 1000 and 1150 (N. Akins, personal communication). Age was noted according to the general categories "infant, child, adolescent, adult male, adult female, old adult, adult: sex unspecified, and human: age unreported." Kolmogorov-Smirnov cumulative frequency tests for two samples (Siegel 1956:127-136) were used in paired comparisons of the Pueblo Bonito age profile to the age profile from each of these sites. Only the age profile for the Kin Neole cemetery differed significantly from that of Pueblo Bonito at the 0.01 level. This is largely due to the relative abundance of infants and children at Kin Neole and the relative paucity of these age groups represented in the Pueblo Bonito sample. It is possible that some of this difference may be attributable to skeletal recovery bias introduced by the excavators. Despite the varying size of the skeletal samples considered (between 20 and 112 individuals), it can be suggested that the general age profiles undifferentiated by sex do not distinguish Pueblo Bonito from its surrounding smaller contemporaneous occupations.

A more detailed demographic study is possible for the skeletons derived from the four contemporaneous burial rooms excavated by Judd. Information on the age, sex, and gross skeletal pathologies was collected by the author; 95 of the 112 individuals reported by Judd from these rooms are retained in the Smithsonian collections (Table 2). Given that these rooms are roughly contemporaneous and are immediately adjacent to each other in the Pueblo Bonito room complex, it can be argued that this area represents a formal "cemetery" or is at least the closest thing to a spatially distinct, temporally discrete interment area noted to date in Chaco Canyon. Utilizing five-year age classes, the Kolmogorov-Smirnov test for paired comparisons of each room with every other room shows the variations in age profiles among the rooms not to be highly significant statistically. Since these rooms probably served as mortuary facilities roughly contemporaneously, and they do not show significant age segregation among the individuals recovered, the age information

Table 1. Reported age distributions, Chacoan sites.

Age Categories	Pueblo Bonito	BC 51	BC 53	BC 59	Kin Neole
Infant	9	8	5	5	23
Child	14	6	2	17	6
Adolescent	4	6	1	9	4
Adult Male	27	9	5	5	4
Female	52	8	6	10	11
Adult, Sex Unspecified	0	14	1	20	20
Old Adult	6	0	0	0	0
Human, Age Unreported	0	6	0	7	0
Total	112	57	20	73	68

Table 2. Age distribution, Pueblo Bonito burial rooms.

Age Class	Room 320				Room 326				Room 329				Room 330			
	M	F	?	Total	M	F	?	Total	M	F	?	Total	M	F	?	Total
0-1 yr.	-	-	1	1	-	-	0	0	-	-	0	0	-	-	0	0
1-4.9 yr.	-	-	0	0	-	-	2	2	-	-	5	5	-	-	1	1
5-9.9 yr.	-	-	2	2	-	-	0	0	-	-	5	5	-	-	4	4
10-14.9 yr.	-	-	2	2	-	-	1	1	-	-	2	2	-	-	2	2
15-19.9 yr.	1	1	2	4	0	0	1	1	0	0	0	0	1	0	0	1
20-24.9 yr.	0	0	0	0	0	1	0	1	1	3	0	4	3	4	0	7
25.29.9 yr.	0	3	0	3	1	1	0	2	0	3	0	3	4	2	0	6
30-34.9 yr.	0	2	0	2	1	1	0	2	0	0	0	0	3	2	0	5
35-39.9 yr.	0	2	0	2	2	2	0	4	1	0	0	1	3	0	0	3
40-44.9 yr.	0	1	0	1	0	1	0	1	0	2	0	2	1	0	0	1
45-49.9 yr.	0	2	0	2	0	1	0	1	0	1	0	1	1	0	0	1
50 plus yr.	0	2	0	2	0	3	0	3	0	1	0	1	0	1	0	1
?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	1	13	7	21	4	10	4	18	2	10	12	24	16	9	7	32

from these rooms was combined into a single age profile (Table 3). This yielded a series of 95 individuals--a sufficiently large sample from which to construct a composite life table (Tables 4 and 5).

Comparisons of this life table (Table 5) to model life tables derived from small-scale populations by Weiss (1973) or to populations from other prehistoric Pueblo groups in the Southwest (Palkovich 1980) show that the Pueblo Bonito skeletal series does not reflect a typical age distribution. Paucity of infants is clearly a factor; only 20% of the individuals recovered were 10 years of age or younger at death. Only a single individual less than one year of age at death was noted--a full term fetus retained in the pelvic cavity of the mother (Judd 1964). Despite the generally good to excellent preservation of the observed skeletal remains, from a demographic standpoint infants and children are underrepresented. While excavation and recovery bias are suspected, purposeful mortuary bias must be considered as well.

In addition to the unusual age distribution, there is a notable disparity in the sex distribution in that females are nearly twice as frequent in the sample as males (43 to 23, respectively). Again, preservation was excellent and adult material seems to have been systematically retained in the collection. Despite some difficulty in obtaining an accurate accounting of individuals because of the disturbed condition of the remains recovered from each room, sex distinctions based on both cranial and post-cranial remains clearly show this unusual sex ratio. Again, differential mortuary practices may be significantly altering the observed sex distribution.

Biological Stress

Having established some of the basic demographic features of the Judd burial cluster, the patterns and implications of biological stress exhibited skeletally by this group can be explored further. Based on their assessment of both biological and mortuary evidence, Akins and Schelberg (this volume) suggest that the skeletal remains recovered from Judd's four rooms represent one of two separate (social) "lineages" noted among the Bonito material. Another cluster of burial rooms was excavated by Pepper, and he published a detailed account of the goods recovered with these individuals (Pepper 1909). While descriptions of the skeletal remains and a full accounting of age/sex information is lacking in his report, it is clear from his description of the burial room cluster and Akins and Schelberg's analysis of both Pepper's and Judd's clusters that they most likely represented high ranking lineages in a stratified Chacoan population. Pepper's cluster evidenced a wealth of grave goods befitting a high ranking lineage. Judd's cluster, though afforded a complex of rooms as a burial facility and therefore having special treatment not found in other instances, had fewer grave goods and therefore possibly represented a lower-ranking lineage. Differential treatment within the lineages is also evidenced by the unequal distribution of goods among individuals within each room cluster. The special status accorded these individuals at death may have also been a factor producing the skewed observed age profile as noted earlier.

If it can be suggested that these were indeed ranking lineages and therefore the individuals had favored or special access to resources, it is possible that this favored access may have extended not only to ritual items and the burial treatment of individuals, but also to other resources--such as food. It is possible to test the idea that there would be fewer cases of dietary stress or less severe skeletal involvement resulting from the stress of morbidity/mortality impact for the series from Judd's cluster than the characteristic pattern of dietary stress often observed for prehistoric pueblo groups throughout the Southwest. In other words, perhaps the favored status of the individuals interred in a burial room also afforded them a buffer that included sufficient dietary resources; thus the biological impact of nutritional stress would be less severe for such a group.

From this preliminary analysis, it is immediately apparent that at least the general age profile comparisons argue to the contrary. The Pueblo Bonito group is essentially like those populations living in nearby smaller pueblos, at least in terms of demographic characteristics (leaving aside for the moment possible age biases introduced by mortuary practices or excavation recovery procedures).

Table 3. Age distribution, all rooms combined, Pueblo Bonito.

Age Class	Male	Female	Sex Unknown	Total
0-1 yr.	-	-	1	1
1-4.9 yr.	-	-	8	8
5-9.9 yr.	-	-	11	11
10-14.9 yr.	-	-	7	7
15-19.9 yr.	2	2	2	6
20-24.9 yr.	4	8	0	12
25-29.9 yr.	5	9	0	14
30-34.9 yr.	4	5	0	9
35-39.9 yr.	6	4	0	10
40-44.9 yr.	1	4	0	5
45-49.9 yr.	1	4	0	5
50 plus yr.	0	7	0	7
Total	23	43	29	95

Table 4. Pueblo Bonito composite life table, unsmoothed.

Age Class	D_x	d_x	l_x	q_x	L_x	T_x	e^0_x
0-1 yr.	1	1.05	100.00	0.0105	99.48	2567.89	25.67
1-4.9 yr.	8	8.42	98.95	0.0851	378.96	2468.41	24.95
5-9.9 yr.	11	11.58	90.53	0.1279	423.70	2089.45	23.08
10-14.9 yr.	7	7.37	78.95	0.0934	376.33	1665.75	21.10
15-19.9 yr.	6	6.32	71.58	0.0883	342.10	1289.42	18.01
20-24.9 yr	12	12.63	65.26	0.1935	294.73	947.32	14.52
25.29.9 yr.	14	14.74	52.63	0.2801	226.30	652.59	12.40
30-34.9 yr.	9	9.47	37.89	0.2499	165.78	426.29	11.25
35-39.9 yr.	10	10.53	28.42	0.3705	115.78	260.51	9.17
40-44.9 yr	5	5.26	17.89	0.2940	76.30	144.73	8.09
45-49.9 yr.	5	5.26	12.63	0.4165	50.00	68.43	5.41
50 plus yr.	7	7.37	7.37	1.0000	18.43	18.43	2.50

Table 5. Pueblo Bonito composite life table, smoothed.

Age Class	D_x	D_x	d_x	l_x	q_x	L_x	T_x	e^0_x
0-1 yr.	1	1	1.07	100.00	0.0107	99.47	2646.52	26.46
1-4.9 yr.	8	6.67	7.14	98.93	0.0722	381.44	2547.05	25.75
5-9.9 yr.	11	8.67	9.29	91.79	0.1012	435.73	2165.61	23.59
10-14.9 yr.	7	8.00	8.57	82.50	0.1039	391.08	1729.88	20.97
15-19.9 yr.	6	8.33	8.92	73.93	0.1207	347.35	1338.80	18.11
20-24.9 yr.	12	10.67	11.43	65.01	0.1758	296.48	991.45	15.25
25-29.9 yr.	14	11.67	12.50	53.58	0.2333	236.65	694.97	12.97
30-34.9 yr.	9	11.00	11.78	41.08	0.2868	175.95	458.32	11.16
35-39.9 yr.	10	8.00	8.57	29.30	0.2925	125.08	282.37	9.64
40-44.9 yr.	5	6.67	7.15	20.73	0.3449	85.78	157.29	7.59
45-49.9 yr	5	5.67	6.07	13.58	0.4470	52.73	71.51	5.27
50 plus yr.	7	7	7.50	7.51	1.0000	18.78	18.78	2.50

Even more persuasive evidence to the contrary is noted among the observed pattern of gross skeletal pathologies. However, because of the great protein and caloric requirements during early childhood growth, subadults are particularly susceptible to nutritional stress. Patterns of childhood morbidity and mortality (observed as incidence of nutrition-related skeletal pathologies and age-specific mortality rates) are sensitive indicators of both the age-specific nutritional adequacy and the overall nutritional status of the population (Palkovich n.d.; Cook 1976). Few nutrition-related pathologies would be expected if the Pueblo Bonito subadults received an adequate diet due to their social status. Among the 20 juveniles aged 0-10 years recovered from Judd's cluster, five cases of porotic hyperostosis, four cases of cribra orbitalia, and four cases of endocranial lesions are evident; in all, 10 individuals (50%) are affected. A similarly high incidence rate of these pathologies has been noted at a number of prehistoric pueblos (Palkovich 1980, n.d.). Several studies of the etiology of, and the correlations among, these pathologies in prehistoric Southwestern groups suggest iron deficiency anemia associated with general dietary inadequacies, nutritional stress, and synergistic infectious insults as the underlying cause of this pathology pattern (El-Najjar and others 1975, 1976; El-Najjar 1977; Von Endt and Ortner 1982). In addition, one juvenile evidences a typical case of skeletal tuberculosis (Palkovich, lab notes; Morse 1961:500; Ortner and Putschar 1981:170-173), again indicating significant infectious disease involvement in the once living Chacoan population. Subadult dietary inadequacy clearly had a significant morbidity/mortality impact even among these high-ranking Chacoan lineages.

Conclusions

This study suggests that status may not have been enough to buffer the marked biological effects of dietary inadequacy that affected the prehistoric group interred in this Pueblo Bonito room cluster. The argument Akins and Shelberg (this volume) present for status differentiation among the various pueblo occupations represented in Chaco Canyon burial patterns is strongly persuasive. The biological evidence of notable morbidity and mortality effects, at least partially attributable to nutritional deficiencies found even in a ranking linages, is also suggestive. Further detailed studies of the skeletal series available from Chacoan sites may help clarify the extent, severity, and potential differential impact dietary and disease problems may have had for these populations and the ultimate biological and societal toll these groups may have suffered as a result of their nutritionally marginal agrarian existence.

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TRENDS IN CERAMIC IMPORT AND DISTRIBUTION IN CHACO CANYON

H. Wolcott Toll

Abstract

Ceramic samples from four small Chaco Canyon sites dating from the tenth through thirteenth centuries and from Pueblo Alto, a "town" dating to the same approximate period, are discussed in reference to the redistribution model developed for the Chaco Anasazi. Through time an increasing proportion of the ceramics found at these sites can be identified as having been made in the Chuska area to the west, reaching 60% at their most abundant. There are some qualitative and quantitative suggestions that some specialization in ceramic production may have occurred in the Chuska area. There are also differences between small site and large site ceramics, including higher relative frequencies of Chuska ceramics and of grayware jars at Alto, and far higher absolute numbers of ceramics of all kinds. While these and other findings can be seen to concur with some aspects of the redistribution model, it cannot be said that the ceramics in Chaco demonstrate redistribution, especially not of the ceramics themselves.

Purpose, Background, Framework

Taking for granted that some form of regional system existed within the San Juan Basin, and that the system moved large quantities of goods, this paper's purpose is to give a brief overview of ceramic distribution in Chaco and to examine how the ceramic evidence conforms to the cultural models that have been generated.

Based on both temper and stylistic analyses, ceramics found in Chaco Project excavations in the central canyon can be seen to roughly follow the same source pattern through time as do the lithics (Cameron, this volume).

At early sites (Basketmaker III) there are some identifiable long distance items, with items from the San Juan River area to the north occurring in higher frequencies than they do in later contexts. Also at this time period relative frequencies of a temper suspected to be local are greatest.

During the period A.D. 920-1020, chalcedonic cement sandstone, a temper thought to come from south of the canyon, perhaps the Red Mesa Valley, reaches its highest relative frequencies of up to 30% in the graywares. Simultaneously, temper from the Chuska Valley 60 km to the west appears in substantial frequencies of from 10-20% in graywares and considerably less in whitewares. The great majority of ceramics from the Chuska area are tempered with a distinctive igneous material, trachyte, which allows reliable identification of ceramics from that area (Arnold 1980; Loose 1977; Shepard 1956; Windes 1977).

Through time graywares in particular can be seen to have come increasingly from the Chuska area, reaching 60% during the early twelfth century. Ceramics from the San Juan area and northeastern Arizona are also present, but during the full-scale operation of the Chaco system trachyte is by far the dominant identifiable imported temper.

In our latest proveniences, which extend into the 1200s, the percentages of Chuska sherds decline somewhat, and there is an increase in San Juan ceramics. The small sample from this terminal period makes the identification of this trend tentative (Toll and others 1980).

In all periods there is a large percentage of ceramics that cannot be stylistically and geologically discounted as local, but substantial import of ceramics can be confidently identified. It has been proposed by Judge (1979) and Schelberg (1982) that the "Chaco Phenomenon" may in part be understood as a redistributive system that evolved as a response to unequal resource and precipitation distributions in the basin. The methods spelled out by Renfrew (1975) for defining economic systems from material remains rely basically on distributions in regional space. However, since all of our excavated material comes from the putative center of the system, conventional fall-off rate studies are not available to us. Therefore, it is necessary to assess the conformance of the ceramic data to other expectations generated from the proposition that redistribution took place at the center of the region.

Three subtopics have been selected on the basis of analogies that will not be discussed here (Toll 1978, 1981): specialization of production, differential distribution of ceramics from different sources at large sites as opposed to small sites, and ceramic indications of differences in site function. The expectations relevant to these manifestations are:

(1) If specialization in ceramic production were present and evolved with the system, there should be a reduction in variability in the products of the specialized artisans as compared to nonspecialized products. Thus, within classes grouped by attributes such as type, temper, surface manipulation, and paint, which serve to reduce the number of potential sources for an item, metric variables would be expected to have a smaller variance in specialized than in nonspecialized products, and the diversity of designs and execution should decline. These expectations are founded on the assumption that fewer potters and greater routinization of production would have reduced variability due to personal variation and whim (Rice 1980). The question of whether or not specialists would produce a qualitatively better pot is a difficult one. On the one hand mass production would be expected to cause an inclination toward speedy and efficient, though not necessarily careful, production (Balfet 1965; Plog 1980). On the other hand, as routinization should reduce variability, it should also reduce errors, and the product must be sufficiently high in quality to ensure that its production is a reliable livelihood or hedge. The solution to this problem rests somewhere in the intended function of the vessel, but we are beyond the present scope, and reduction in variability is more easily monitored than increase in quality, in any case.

(2) If large sites--"towns"--in Chaco are regional redistribution points, then they should exhibit a greater diversity of production areas in the ceramics present than do small sites (Fry 1979:509; Rice 1980:67-68). This assumes some consumption of ceramics by inhabitants of large sites, lower likelihood of on-site ceramic production, and that ceramics functioned in the redistribution process in such a way that some would be introduced into the record at the redistribution point. If ceramics themselves were being redistributed, a higher frequency of imported ceramics should be present at the site of redistribution, but imports should be present at recipient sites.

(3) Finally, if large sites are functionally different from small sites, there should be some suggestion of this in the vessel form assemblages and in other indications of function such as sooting on graywares.

The following focuses on Pueblo Alto, a "town," with four smaller sites--29SJ633, 627, 1360, and 629--forming comparative background. Alto was probably first inhabited sometime in the late A.D. 900s; in the early A.D. 1000s through perhaps 1050 the majority of the now visible room block was constructed and the large trash mound began to accumulate. Trash mound deposition seems to have lasted until around A.D. 1100, with occupation of the site continuing until the second half of the 1100s. All of the small sites overlap with Alto in terms of ceramic types present and to some degree in real years. The sample from 633 is on the whole later than much of Alto, and some of it postdates occupation of Alto. Site 627 provides the largest group of sherds that is contemporary with the greatest activity at the towns, considered here to be A.D. 1040-1100; the bulk of material from 627, however, dates to pre-1040 and the post-1040 occupation may be sporadic (Truell 1980). Both 1360 and 629 date largely to pre-A.D. 1040, with some minimal later overlay. In all, the detailed sample from these sites totals to around 16,000 sherds (Table 1). This sample is drawn so as to eliminate vessel duplication insofar as is possible, so that the items in it are nominally equivalent to distinct vessels (for greater detail on all subjects touched here see McKenna 1984; Toll and McKenna 1981, 1982, 1983).

Specialized Production

In 1963 Shepard suggested that specialization of production was present in the Chuska area, based largely on the sheer volume of trachyte temper in Chaco deposits (Shepard 1963). In addition to

Table 1. Occurrence of major wares by site.

Ware	Alto	633	SITE 627	1360	629	Total
Grayware	1917	86	1437	443	325	4208
Mineral-on-white	2604	108	4623	1390	1147	9872
Carbon-on-white	472	80	322	74	72	1020
Redwares	133	16	136	24	41	350
Polished-smudged	130	1	75	22	20	248
Total	5256	291	6593	1953	1605	15,698

Excludes unidentified whiteware and brownwares.
Chi-square combinations

	n	X^2	df	p	C	small
Whole table	15,698	931.751	16	.000	.237	1 cell <5
627, 1360, 629	10,151	15.516	8	.050	.039	
627, 629	8198	3.77	4	.438	.021	
Alto, 633	5547	121.653	4	.000	.146	
WW, GW 5 sites	15,100	423.928	4	.000	.165	
WW, GW all small sites	10,107	14.618	3	.002	.038	
WW, GW by 627, 1360, 629	9833	2.421	2	.298	.016	
WW, GW 633, Alto	5267	5.118	1	.024	---	

WW=whiteware, GW=grayware

the volume and technical quality Shepard noted, tentative support for the presence of specialization can be seen in examination of metric variables in trachyte-tempered vessels, as compared to vessels with two classes of sandstone temper (Tables 2 and 3). Particularly in the the variable least influenced by functional considerations, the width of the rim fillet, trachyte-tempered items have consistently smaller within-type coefficients of variation (standard deviation divided by the mean) than do the sandstone classes. It must be stressed that sandstone is far more widely distributed and on the whole less distinctive than is trachyte, so it is likely that the sandstone-tempered group contains unidentified production subsets, but even the chalcedonic cement sandstone groups (which are presumably more localized) are more erratic than the trachyte-tempered groups. In the Pueblo II and Pueblo II-III corrugated types the coefficient of variation is less than 25% for all six trachyte groups, while only two of seven sandstone or chalcedonic sandstone groups are 25% or less (Table 2). While there is considerable regional stylistic similarity visible in graywares, there is also at least a suggestion that some specialization occurred in the Chuska area based on this reduced variablility. Perhaps contradicting this interpretation is the remarkable similarity in means and variances of the neck banded and neck corrugated groups that predate the Pueblo II and II-III corrugated types. Within this tight group there is less apparent patterning by temper, however.

Estimated orifice diameters of grayware type groups also show smaller standard deviations in the trachyte-tempered vessels than in the sandstone tempered vessels, though the differences are less marked (Table 3). Other patterns may be observed in the orifice diameter data. The Pueblo II and II-III corrugated vessels are mostly larger than the neck banded vessels, and there is a marked difference between even the transitional neck corrugated and the completely corrugated groups. The four largest means are all trachyte-tempered corrugated groups and three of these are from Alto. Truell (personal communication) notes that around A.D. 1000, which coincides with the inception of Pueblo II corrugated and its size increase, there was also an increase in storage area in smaller Chaco sites. In this same vein, it is interesting that the two sandstone-tempered Pueblo III corrugated groups show the smallest means of any grayware group.

Neither of these two metric variables is significantly associated with the site at which they were found, suggesting that imports at 627 and Alto came from the same pool (Toll 1981:Table 5). At both 627 and Alto significant associations are present between mineral painted, trachyte-tempered whitewares and fine squiggle hatchure design, also suggesting at least some areal earmarking of pottery. The nature of this possible specialization is not clear--what would be most informative is excavation of sites involved with ceramic production in the Chuska Valley. Speculatively, however, the similarity of Chuska to other grayware jars may indicate that the specialization was not a full-time one.

Large Site-Small Site Distributions

Comparison of the identified exotic temper assemblages at Alto and 627 demonstrates a significant association of trachyte-tempered vessels with Alto in some types. Except in the case of infrequent types from the end of a site's occupation, which often show a radical jump in the percent of imports, Figures 1 and 2 show that the presence of trachyte temper in both whitewares and graywares is consistently higher at Alto through typological time. The jumps in trachyte percent in terminal graywares at 629 and 1360 are in part the result of small samples, but it is also possible that they indicate cessation of on-site or nearby ceramic manufacture. These two "terminal" groups also show higher variability in diameter than the other groups (Table 3). The high frequency visible for 627 in the "Carbon" time period is an artifact of the typological time placements used. The pattern observed at Pueblo Alto was for most carbon-painted ceramics to be Chuskan until circa A.D. 1100, at which time there was a marked shift to use of carbon paint, and many nontrachyte-tempered items appear. Since 627 did not see intensive use as late as did Alto, 627 shows as having a higher percent of trachyte in its last period of use. Within-type, between-site comparisons of temper assemblages at 627 and Alto indicate that the diversity of sources, as measured by the Shannon Weaver diversity index (Lasker 1976), is greater at Alto during the period in which the system was operating at its greatest extent. This apparent support

Table 2. Culinary ware rim fillet width statistics by temper group, site, and temper; jars, unmixed trachyte, and groups of 10 or more only.

Type/ Site-Temper	n	Mean mm	Standard Deviation	Range	Standard Error	C.V. %
Wide Neckbanded/						
627 Trachyte	15	15.4	4.306	10-28	1.1	28.0
627 Sandstone	88	16.1	2.609	10-22	.3	16.2
629 Sandstone	20	17.4	3.086	13-25	.7	17.7
1360 Sandstone	38	16.4	3.017	13-27	.5	18.4
627 Chalcedonic SS	25	16.3	3.509	9-23	.7	21.5
1360 Chalcedonic SS	18	16.0	4.1	10-26	1.0	25.8
Narrow Neckbanded/						
Alto Trachyte	13	18.9	2.842	14-23	.8	15.0
627 Trachyte	44	15.6	3.773	6-24	.6	24.1
1360 Trachyte	20	16.4	3.952	10-22	.9	24.1
Alto Sandstone	25	16.1	4.558	9-31	.9	28.3
627 Sandstone	140	14.0	3.414	7-25	.3	24.4
629 Sandstone	31	15.2	4.008	7-22	.7	26.3
1360 Sandstone	91	15.3	2.909	10-22	.3	19.0
627 Chalcedonic SS	33	16.0	3.575	9-24	.6	22.3
1360 Chalcedonic SS	26	15.6	2.686	10-20	.5	17.2
Neck Corrugated/						
627 Trachyte	15	13.8	3.364	9-22	.9	24.4
627 Sandstone	48	14.3	3.913	7-27	.6	27.4
629 Sandstone	10	14.4	3.406	11-20	1.1	23.6
629 Chalcedonic SS	10	16.4	3.470	10-22	1.1	21.2
1360 Sandstone	24	15.0	3.388	10-23	.7	22.6
PII Corrugated/						
Alto Trachyte	107	19.9	4.486	10-38	.4	22.5
627 Trachyte	132	20.7	4.815	10-32	.4	23.3
629 Trachyte	11	17.5	2.841	13-21	.9	16.2
1360 Trachyte	21	17.0	3.464	10-22	.8	20.4
Alto Sandstone	81	24.2	6.704	10-45	.7	27.8
627 Sandstone	218	24.3	7.432	10-53	.5	30.6
1360 Sandstone	13	18.3	4.479	13-28	1.2	24.4
Alto Chalcedonic SS	15	23.3	5.824	15-32	1.5	25.0
627 Chalcedonic SS	20	22.0	7.211	10-38	1.6	32.8
PII-III Corrugated/						
Alto Trachyte	51	20.8	4.435	6-30	.6	21.3
627 Trachyte	30	21.6	4.430	13-30	.8	20.5
Alto Sandstone	35	25.4	10.333	9-50	1.7	40.7
627 Sandstone	41	24.8	6.834	15-43	1.1	27.5
PIII Corrugated/						
Alto Trachyte	11	21.2	7.097	6-30	2.1	33.5
Alto Sandstone	18	19.7	5.750	10-32	1.4	29.2
627 Sandstone	29	18.4	6.156	10-34	1.1	33.4

Table 3. Culinary ware estimated orifice diameter statistics by type group, site, and temper; jars, unmixed trachyte, and groups of 10 or more only.

Type/ Site-Temper	n	Mean mm	Standard Deviation	Range	Standard Error	C.V. %
Wide Neckbanded/						
627 Trachyte	10	172.0	21.884	140-200	6.9	12.7
627 Sandstone	72	181.9	49.869	80-350	5.9	27.4
629 Sandstone	20	169.5	38.282	110-230	8.6	22.6
1360 Sandstone	37	169.2	38.846	70-250	6.4	23.0
627 Chalcedonic SS	18	181.1	43.235	120-270	10.2	23.9
1360 Chalcedonic SS	17	167.3	54.000	90-305	13.1	32.3
Narrow Neckbanded/						
Alto Trachyte	12	194.6	46.341	80-240	13.4	23.8
627 Trachyte	38	199.3	58.485	85-320	9.5	29.3
1360 Trachyte	19	216.6	50.112	155-330	11.5	23.1
Alto Sandstone	23	177.4	44.667	100-265	9.3	25.2
627 Sandstone	113	173.0	58.116	50-350	5.5	33.6
629 Sandstone	29	204.5	43.616	115-290	8.1	21.3
1360 Sandstone	87	173.4	46.106	50-290	4.9	26.6
627 Chalcedonic SS	31	185.3	55.165	110-350	9.9	29.8
1360 Chalcedonic SS	23	172.0	55.036	60-270	11.5	32.0
Neck Corrugated/						
627 Trachyte	14	198.9	65.697	105-350	17.6	33.0
627 Sandstone	37	184.5	55.700	65-300	9.2	30.2
629 Sandstone	10	180.0	43.843	130-250	13.9	24.4
629 Chalcedonic SS	10	196.5	41.570	120-260	13.1	21.2
1360 Sandstone	23	187.8	53.083	110-330	11.1	28.3
PII Corrugated/						
Alto Trachyte	103	221.9	52.300	110-340	5.2	23.6
627 Trachyte	101	213.7	52.439	95-350	5.2	24.5
629 Trachyte	11	223.2	72.155	70-310	21.8	32.3
1360 Trachyte	19	214.7	59.941	135-350	13.8	27.9
Alto Sandstone	77	204.3	54.264	90-335	6.2	26.6
627 Sandstone	163	216.0	55.378	70-350	4.3	25.6
1360 Sandstone	12	177.1	42.020	105-250	12.1	23.7
Alto Chalcedonic SS	15	216.7	37.591	150-275	9.7	17.4
627 Chalcedonic SS	14	215.7	72.850	80-330	19.5	33.8
PII-III Corrugated/						
Alto Trachyte	50	227.6	61.389	80-350	8.7	27.0
627 Trachyte	28	216.6	40.871	140-305	7.7	18.8
Alto Sandstone	35	193.4	53.930	70-280	9.1	27.9
627 Sandstone	37	217.8	54.385	80-320	8.9	25.0
PIII Corrugated/						
Alto Trachyte	11	223.6	53.155	140-330	16.0	23.8
Alto Sandstone	18	146.9	47.809	70-240	11.3	32.5
627 Sandstone	24	154.6	42.934	70-220	8.8	27.8

for the model must be conditioned by the caveat that the vast majority of identified imports from this time period are from the Chuska Valley, so that the diversity of identified imports (as opposed to overall temper assemblage) actually declines at Alto. Within-type comparisons provide some control for the imperfect contemporaneity, but time may still have some effect on the result. Though quantities vary some, the similarity in trends among all sites is indeed striking (Figures 1 and 2).

In the Chaco assemblages there is a consistent, significant association between grayware jars and trachyte. In turn, there is a significant association between Alto and gray jars (35% gray jars) when compared to the small sites--18-22% at the three earlier small sites (Tables 1 and 4). The vessel form assemblage is more diverse at small sites, 627 and the somewhat earlier 629, than it is at Alto. These facts suggest that the activities relating to ceramics were somewhat different at small as opposed to large sites. One explanation for these differences is that while there is clear evidence for habitation at Alto, there may have been some different focus of activity, perhaps involving a smaller range of daily activity at Alto than at the smaller sites or perhaps involving activities not present at smaller sites. Ceramic manufacture of any sort seems less likely at Alto since some of the forms less frequent or missing at Alto are pipes and effigies, which might be considered ad hoc productions. No ceramic manufacturing tools or materials are known from Alto, but they are rare at small sites as well; of the sites under consideration here, the best evidence for production is at 1360 (McKenna 1984).

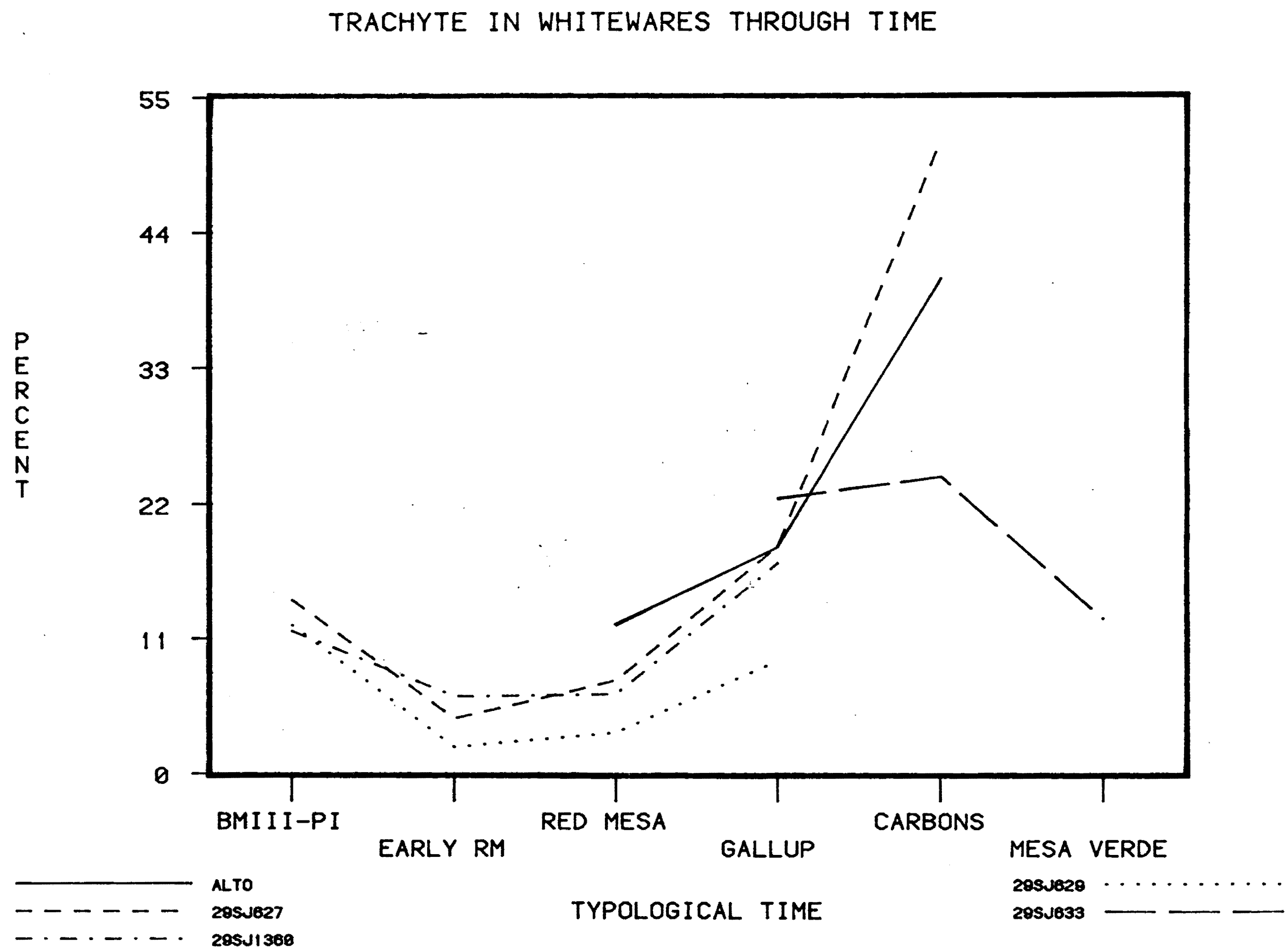
That there is an association of jars with Alto suggests that Alto may have been more heavily involved with transport and/or storage than the smaller sites where bowls and ladles are relatively more common. These associations are further strengthened by the fact that while a ware comparison between 627 and 629 shows no difference, both of these sites are significantly different from Alto, where graywares and polished smudged wares occur at higher than expected frequencies (Table 1; 1360 differs from 629 and 627 principally because of its low redware frequency). Alto also differs in the relative frequency of carbon-painted ceramics, but the presence of carbon wares is largely a chronological phenomenon. It is carbon-painted ceramics that contribute heavily to the statistical difference from the other sites exhibited by the late small site, 633. Even when mineral-painted and carbon-painted whitewares are lumped, the Alto graywares deviate most from expected values, giving a relatively high coefficient of contingency (C=.165). A similar test of the three earlier small sites (629, 1360, 627) shows no difference, but one including 633 is significant, though with a low coefficient of contingency (C=.038). Thus some of the increase in graywares at Alto may be temporal, but the increase is so great that a functional difference is also implied. It is noteworthy that the higher small-site frequency for grayware at 633 (28%) is very similar to the latest, post-Trash Mound grayware frequency in Alto's Kiva 10 (31%) (Table 7).

The actual function of vessels is generally a thorny question to which truly satisfying answers are not available. However, the presence of soot on a vessel's exterior gives some idea that at least one of the functions of that vessel was cooking. Trachyte has a mineralogical composition and an angular grain form that make it well suited for cooking vessels (Rye 1976; Shepard 1956; Windes 1977). However, at three of four sites tests of association of temper with sooting yield chi-square values that are not significant at .05. The one site where the association between temper and sooting is significant is Alto. At all sites, sooting of trachyte vessels runs slightly higher than the statistical expectation, but only at Alto significantly so. Even at Alto the coefficient of contingency is low: C=.074. This may be taken as a suggestion that some recognition of the thermal qualities of such jars was present, but that at least at small sites, it was not the main reason for their import. Alto is also the only site where sooted graywares outnumber the unsooted ones. While 629 differs from 627, 1360 and 633 by virtue of the relative lack of sooting at 629, the other three small sites (633, 1360, and 627) are statistically similar (Table 5). All the small sites vary markedly from Alto. This result makes more tenuous the expectation generated by vessel form that Alto is less oriented to daily activity. Certainly cooking can involve suprahousehold functions as can be seen in the presence of large, formal, probably communal firepits in the central plaza. These firepits may well postdate the Alto Trash Mound, further complicating the site interpretation, but perhaps helping ex-

Figure 1. Occurrence of trachyte temper in whitewares through typological time. Typologically identifiable whitewares have been placed in temporally determined lumps and the percentage of vessels containing trachyte temper is calculated for each temporal lump. Distortion is present at 1360 and especially 627 because (1) all items containing any trachyte are included, rather than those with dominant trachyte as at the other sites, and (2) the lump of "Chuska Whitewares" included in "Carbons" is likely to contain earlier sherds at 627. The numbers of trachyte-tempered items represented by percents in the figure are:

	BMIII-PI	Early RM	Red Mesa	Gallup	Carbons	Mesa Verde
Alto			31	206	144	4*
627	28	7	183	159	112	-
1360	13	7	42	10	-	-
629	29	3	17	4	-	-
633	-	-	-	5	12	4

*100% of the "Mesa Verde" at Alto



TRACHYTE IN WHITEWARES THROUGH TIME
55
44
33
22
11
0
PERCENT
BMIII-PI
EARLY RM
RED MESA
GALLUP
CARBONS
MESA VERDE
TYPOLOGICAL TIME
ALTO
29SJ627
29SJ1360
29SJ629
29SJ633

Figure 2. Occurrence of trachyte temper in graywares through typological time. Types are not lumped here; percentages are shown for rough sort categories. The number of trachyte items represented by percents in the figures are:

	Lino	Wide NB	Narrow NB	Neck Cor	PII	PII-III	PIII
Alto	-	-	27	7	122	59	15
627	0	17	50	17	145	34	11
1360	2	4	22	9	26	-	-
629	4	3	8	6	13	-	-
633	Insufficient samples						

TRACHYTE IN GRAYWARES THROUGH TIME

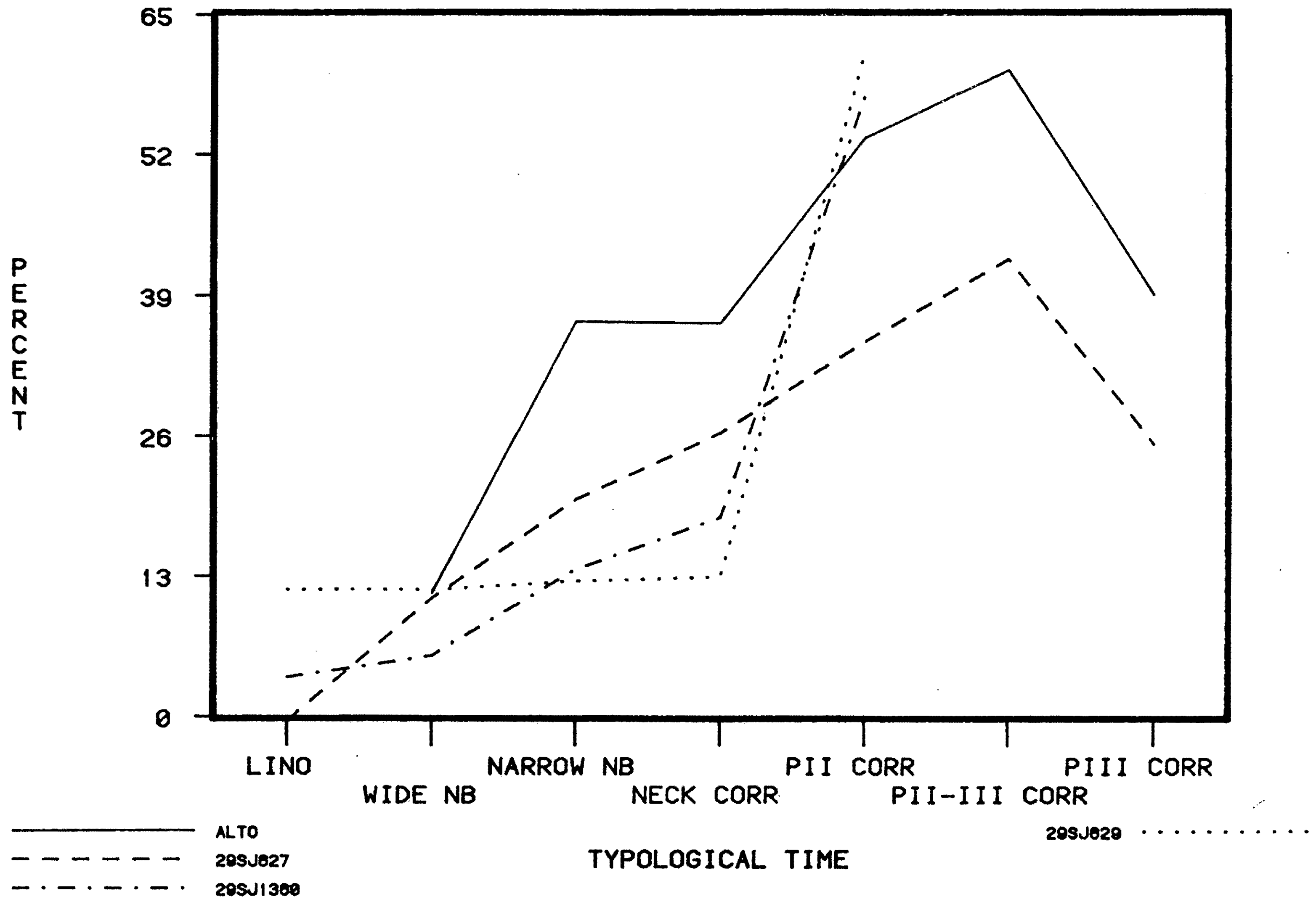


Table 4. Rim sherd vessel forms by site.

	SITE					
Form	Alto	633	627	1360	629	Total
Bowl	1972	146	3332	859	734	7043
Ladle	183	15	269	65	41	573
Pitcher	136	1	183	43	18	381
Seed jar	28	1	46	7	5	87
Canteen	20	2	46	10	12	90
Tecomate	22	4	119	29	12	186
Olla	132	2	146	46	21	347
Whiteware jar	107	7	203	61	71	449
Grayware jar	1406	71	1120	314	196	3107
Total	4006	249	5464	1434	1110	12,263

Excludes gourd jars, duck pots, effigies, mugs, gray pitchers, pipes, and red jars; all bowls lumped.

Chi-square combinations

	n	X^2	df	p	C	small E
Whole table	12,263	430.252	32	.000	.184	3 cells <5
B,WWJ,L,P by Alto,627,629,1360	8277	45.146	9	.000	.074	
WWJ,L,P,Olla	1725	55.7	9	.000	.177	

B=bowl, WW=whiteware, J=jar, L=ladle, P=pitcher

Table 5. Sooting on graywares by site.

	SITE					
	Alto	633	627	1360	629	Total
Sooted	964	30	481	98	73	1646
Not sooted	948	54	935	227	244	2408
Total	1912	84	1416	325	317	4054
Soot:No soot	1.02	.56	.51	.43	.30	

Chi-square combinations	n	X^2	df	p	C
Whole table	4054	158.367	4	.000	.194
Small sites only	2142	15.306	3	.002	.084
Small sites less 629	1825	1.948	2	.378	.033

Table 6. Distribution of sooting on graywares in Pueblo Alto proveniences.

Sooting	All Rooms	Pre-1100 Pitstructures	Pre-1040 Trash Mound	1040-1120 Trash Mound	Kiva 16 (1100-1130)	Kiva 10 post 1100	Total
Sooted	101	30	38	679	27	89	964
Unsooted	31	31	77	723	46	40	948
Total	132	61	115	1402	73	129	1912
Soot: No soot	3.26	.97	.49	.94	.59	2.22	

Chi-square	n	X^2	df	p	C
Whole table	1912	75.174	5	.000	.194

Table 7. Distribution of vessel forms at Pueblo Alto.

Vessel Form	All Rooms	Pre-1100 Pitstructures	Pre-1040 Trash Mound	1040-1120 Trash Mound	Kiva 16 (1100-1130)	Kiva 10 post 1100	Total
White bowl	165	103	177	1233	81	234	1993
Red bowl	9	6	2	52	5	45	119
Smudged bowl	17	15	3	62	11	19	127
Ladle	26	9	18	177	11	29	270
Pitcher	6	4	3	121	15	24	173
Seed jar	4		1	19	1	6	31
Canteen	3	1	2	14	2	1	23
Tecomate	2			17	2	2	23
Olla	15	11	8	97	11	12	154
Mug	1						1
Duckpot	1					1	2
Cylinder jar				1			1
Whiteware jar	96	9	38	323	20	20	506
Redware jar	4				1		5
Grayware jar	134	61	116	1401	74	129	1915
Grayware pitcher				4			4
Miniature	1	2		4	2	4	13
Gourd jar				1			1
Total	484	221	368	3526	236	526	5361

Chi-square comparisons	n	X^2	df	p	C	small E
White bowl, red bowl, smudged bowl, special, olla white jar, gray jar	5334	349.302	40	.000	.248	3 cells <5
Whiteware: bowl, ladle, pitcher, olla jar, closed	3177	127.461	25	.000	.196	2 cells <5
Early/Late Trash Mound by white bowl, ladle, closed, olla, whiteware jar grayware jar	3766	29.547	5	.000	.088	

special=whiteware seed jars, canteens, cylinder jar and tecomates, miniatures, duck pots
closed=whiteware seed jar, canteen, tecomate

plain the high sooting frequency in the late deposits. The high frequency of sooting at Alto requires modification of any simple transport and storage explanations for Alto's preponderance of jars.

As in the case of temper, comparisons of sooting must take into account both site type and site time. With rare exception, occurrence of soot increases at all sites in sequential grayware types. Further, proveniences are present at small sites in which sooted items outnumber unsooted ones. There is considerable variation of soot-present to soot-absent ratios at Alto as well (Table 6). The rooms and the late trash in Kiva 10 (which postdates the Trash Mound) are very high in relative frequency of sooting. Rooms were also found to be high in sooting at 627 and 629, suggesting that sooting may be habitation associated. In the earlier deposits in the Alto Plaza and Trash Mound the early site overall pattern of predominantly unsooted graywares is present. The main Trash Mound--especially the A.D. 1040-1100 portion--is almost exactly evenly split.

The distribution of vessel forms at a similar level of provenience separation reveals that grayware jars do occur in the Alto Trash Mound in higher than expected frequencies when compared either to all provenience groups or to the Kiva 10 deposit, though there are larger contributors to the chi-square values, in part because of the large Trash Mound sample (Table 7). Notable deviations from expected values include more whiteware jars in the rooms than expected, fewer red bowls in the Trash Mound, and fewer grayware jars in Kiva 10, the rooms, and the Plaza.

While the temper assemblages at 627 and Alto are not greatly different in kind, especially when time incongruities are considered, Alto stands well apart from all the small sites when it comes to numbers of vessels present. Based on what we know of the site, a total of 20 habitation rooms is probably a high estimate for the A.D. 1040-1100 period, during which the majority of the Trash Mound was deposited. If, as volume estimates suggest (Windes 1982), the collections we have represent 2.2% of that "Gallup" portion of the deposit, and if our vessel control is good, the total Trash Mound contains representatives of 150,590 vessels! If our volume estimates are short and our sample is 10% (an outside upper estimate), there are still 33,130 vessels represented in this one part of the mound. Dividing by the time span of the deposit gives a pots-per-annum figure many times larger than that for any small site (Table 8) and larger than could be expected for the resident population. To my mind this is one of the better evidences of periodic gatherings of nonresidents at the site. Very speculatively, it may also be suggested that a part of such gatherings may have been to dispose of some item at the conclusion--it is difficult to otherwise explain the quantities of ceramics indicated. If this scenario has merit, the vessel forms suggest that the activities were varied: a high relative frequency of grayware jars both sooted and unsooted; whiteware bowls are numerous, as is true at all five sites, but bowls of all wares are less frequent than usual; pitchers and other closed whiteware forms are relatively abundant (Table 7). While whiteware closed forms are more abundant than in most site deposits, they do not show the heavy dominance observed in sherd counts on the prehistoric roads; moreover, grayware is rare on the roads (Kincaid 1983).

Conclusions

The questions of what so many vessels signify and why so many are Chuskan are not amenable to strictly ceramic answers. Assuming substantial population in the canyon, an argument can be made for fuel supplies in Chaco being inadequate for ceramic production from well before A.D. 1100 in Chaco. In terms of energy efficiency, if you will, it is efficient to bring vessels to Chaco from areas with fuel--and perhaps specialists--but probably not efficient to take them back to areas with fuel such as the perimeters of the Basin (Arnold 1980; Reina and Hill 1978; Samuels and Betancourt 1982; Toll 1981; Warren 1977). Inferring from limited temper information from sites around the system (Marshall and others 1979; Powers and others 1983; Franklin 1980), it does not appear that trachyte-tempered pottery is anywhere near as frequent at non-Chuskan outliers as it is in the central canyon. If redistribution to outliers occurred it does not seem to have involved ceramics either as objects or containers in substantial quantity. The large quantities of vessels at a proposed point of redistribution also bodes ill for the suggestion that ceramics, at least, were redistributed there. The finding that a center

Table 8. Projected ceramic consumption rates for four Chaco sites, with detailed information provided for Pueblo Alto.

Site	% Excavated Rooms etc.	% Excavated Midden	Ceramic Vessel n Rooms	Ceramic Vessel n Midden	Projected Total	Years of use	Pots per annum	Families	Ppa/ family
29SJ629	100	70	922	750	1933	130	14.9	2	7.4
29SJ1360	60	10	1875	213	5255	125	42.0	3	14.0
29SJ627	90	10	5539	1299	19,144	225	85.1	3	28.4
Alto Red Mesa Trash M.		2.2		368	16,727	40	418.2	20	20.9
Alto Gallup Trash Mnd.		2.2		3313	150,509	60	2509.8	20	125.5
Alto Gallup Rooms	10		275		2750	60	45.8	20	2.3
Alto Gallup Kiva 13	3.1		71		2290	60	38.2	20	1.9
Kiva 16	31.8		236		742	30	24.7	20?	1.2
Kiva 10	8.3		555		6687	70	95.5	20?	4.8
Baseline†									
29SJ629			1707			130	13.1	2	6.6
29SJ1360			2088			125	16.7	3	5.6
29SJ627			7225			225	32.1	3	10.7
Alto Gallup Trash Mound			3313			50	55.2	20	2.8

†Baseline figures use only the excavated, vessel controlled sample from each site, and are thus bare minima.

is an apparent dead end for ceramics rather than a dispersal point is not unique--Fry's (1979) findings at Tikal are similar.

Within the canyon the differential distribution of imported ceramics at Alto can be interpreted in several ways. One interpretation is that on an intracanyon level there is evident a conventional fall-off between redistributive point and recipients. Another, not necessarily exclusive interpretation is that these differential distributions may indicate some control of these external resources. If the large numbers of vessels at Alto are from differential consumption by a small population rather than the gatherings proposed, then a status difference is implied. It would be difficult at this point to ascertain if both differential consumption and mass gatherings were occurring, but the quantities are so great that both are more likely than conspicuous consumption alone.

Rather than central Chaco serving as a redistribution node for regional ceramics, the picture that emerges is one of increasing dominance of items--both ceramic and lithic--from the Chuskas. The relationship between Chaco Canyon and the Chuska Valley was a very strong one and the disproportion of pots to people under revised population estimates (Windes this volume) lends credence to proposals of seasonal influx to Chaco. The location of the Alto Trash Mound by two "exterior plazas" at the juncture of numerous roads and its distinctive ceramic composition fit nicely into this scheme. The emphasis placed on Chuskan vessels here should not be allowed to overshadow the large corpus of other tempers, particularly in the mineral-painted whitewares. The Chuskans were by no means the only contributors to Chaco ceramics, merely the largest and most easily identified long-distance group. This ceramic occurrence may reflect regional population distribution as much as it does social connection. The commingling of ceramics in great quantity from a number of sources at sites like Pueblo Alto is evidence for broad geographical interaction. It is hard to resist attributing the possibility of large gatherings to ceremonial functions. It is important to remember that nominally ceremonial gatherings ethnographically have the effect of reapportioning goods to those in need (Ford 1972a,b), as well as maintaining other aspects of the system. In this sense, the ceramic evidence is not a negation of the redistribution model. Two important aspects of this period of large-scale ceramic consumption are that it was relatively brief--from approximately A.D. 1040 to 1100--and that it was concurrent with extraordinary activity in building, faunal consumption, and Chuskan lithic import, and with large extramural trash mound deposition in central Chaco Canyon.

At Alto, the ceramic epilogue to the Trash Mound deposition phase highlights some of these points. Concurrent with the termination of Trash Mound deposition, the region-wide shift to carbon-painted whitewares begins, with carbon paint being predominant by the end of the Alto occupation. Chuskan ceramics remain a large portion of the assemblage, reaching their highest relative frequencies in graywares in Kiva 10. However, in Kiva 10 the overall percentages of graywares decline drastically from those in the Trash Mound (see Table 7), and the sooting frequency rises. With this change the Kiva 10 vessel form assemblage resembles those of smaller sites and pre-Trash Mound Alto. There is also a suggestive decline in culinary jar diameter in the latest corrugated types in Chaco. Unless we are unaware of some late trash deposits, there is a large decrease in absolute numbers of vessels present at Alto. By the thirteenth century Alto seems to have been abandoned; at 633 there are indications of decreasing frequencies of Chuskan ceramics and increasing San Juan ceramics, again probably reflecting both Basin demography and organization (Toll and others 1980).

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Peter McKenna has spent more time looking at Chaco potsherds than anyone I know, and he collected much of the information upon which this paper is based. Tom Windes is also a good source of ceramic information and ideas.

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A REGIONAL VIEW OF CHIPPED STONE RAW MATERIAL USE IN CHACO CANYON

Catherine M. Cameron

Abstract

Analysis of chipped stone material from sites in Chaco Canyon emphasized regional resource exploitation by the identification of sources of raw material. Functional variation was found in the use of some local materials. Five exotic materials were found in significant quantities, and functional variation was observed in the occurrence of some of these exotics. Examination of the falloff curves of exotic chipped stone materials from their source indicated that only Washington Pass chert occurred in unexpectedly high quantities in Chaco Canyon. However, the volume of import of Washington Pass chert does not seem to have been as great as that of other types of imports such as ceramics and architectural timbers. There seems to be no clear evidence for redistribution of chipped stone material from Chaco Canyon; however, there may be evidence of seasonal aggregation of surrounding populations.

Introduction

A total of more than 34,000 pieces of chipped stone was recovered from sites excavated by the Chaco Center. Analysis emphasized regional resource exploitation through the identification of sources of raw material using a material typology devised by Helene Warren (n.d.). The first section of this paper will discuss change in use of local materials through time, task specific selection of local materials, and increasing use of exotic materials during the Classic Bonito phase. The second section will examine lithic data within the framework of models of exchange that have been proposed for Chaco Canyon.

Local Materials

Location

A geologic survey in the Chaco area (Love 1982) identifies local sources of chipped stone raw material within 10 km of the canyon (Figure 1). Local materials used in chipped stone manufacture were primarily silicified woods and pebble cherts. Silicified wood is found in the Kirtland Formation, the Fruitland Formation, and the Ojo Alamo Sandstone. The Ojo Alamo and Quaternary gravel terraces produce pebble cherts and some reworked silicified wood. Most of the locally available material occurs to the north of the canyon.

Change Through Time

Local material was overwhelmingly selected for chipped stone use throughout the Anasazi occupation of the canyon (Table 1). Cherts derived from gravel terraces (High Surface Chert) are most frequent in the earliest time periods (from about A.D. 500 to 800) when they comprise from 20 to 35% of site assemblages. While frequencies of local silicified woods are always high, they increase through time until the mid-A.D. 1000s when they are replaced, in part, by materials from outside the local Chaco area. The switch from High Surface Chert to silicified wood may indicate exploitation of a wider resource area. High surface gravel terraces are found on the mesas bordering the canyon, whereas the sources of silicified wood, while still local, are some distance to the north.

Functional Variation

Local silicified woods range in quality from glossy material with good conchoidal fracture to a dull splintery type. There is evidence of task specific selection of these materials. Hammerstones are often made of Splintery Silicified Wood, and the frequency of flakes of this material at the large town sites is highest during periods of peak construction activity. This material may have been used in the shaping of building stone.

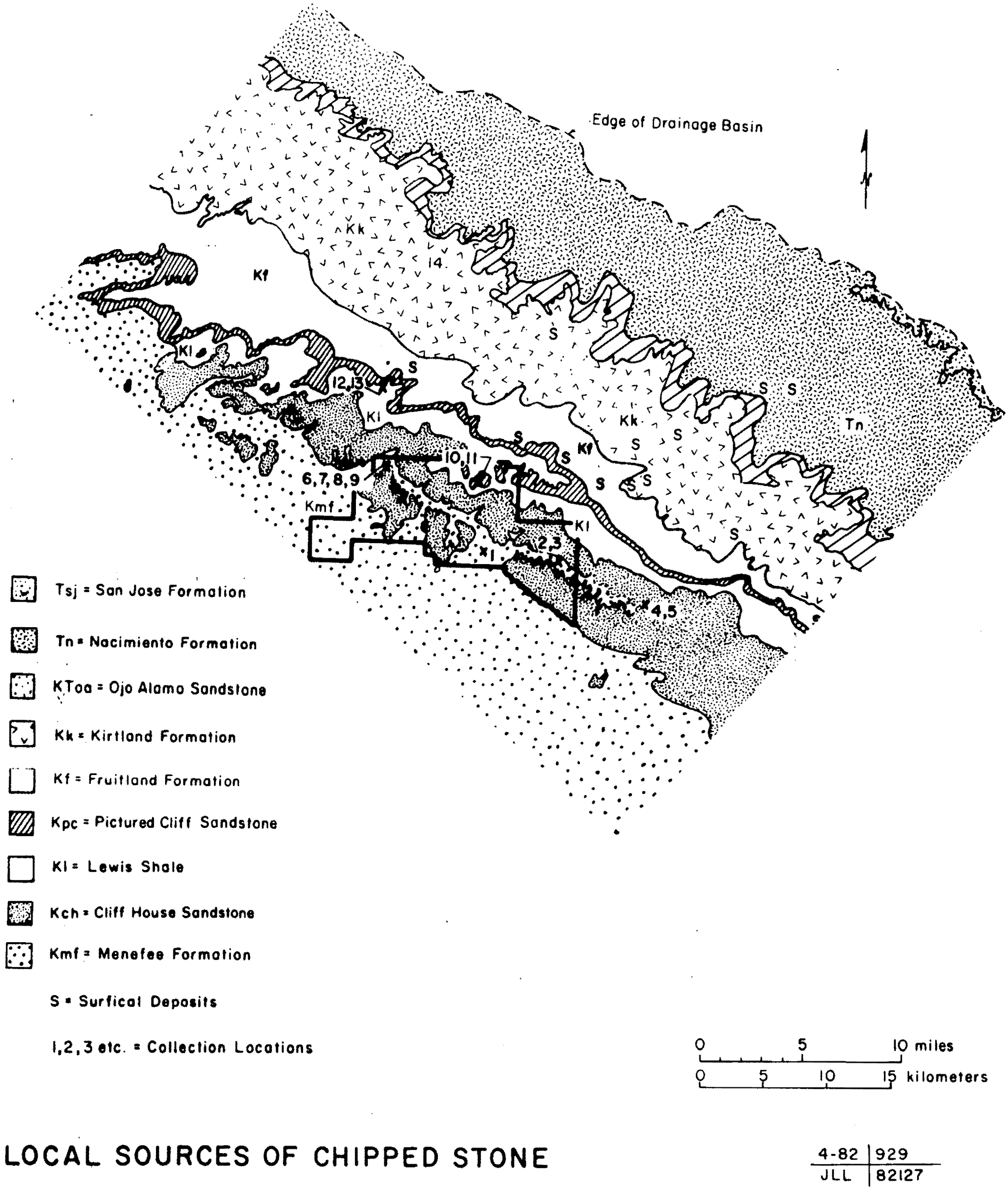

Figure 1. Local sources of chipped stone material.

Table 1. Material type by time period.

	Time / Material	500s	600s	700-820	820-920	920-1020	1020-1120	1120-1220	1220-1320	Total
EXOTIC MATERIAL	Morrison Fm	24 0.9	2 0.7	2 0.2	3 0.4	38 0.4	327 4.3	59 2.6	4 0.9	459
	Yellow-Brn-Spotted	14 0.5	1 0.3	7 0.5	2 0.3	31 0.3	67 0.9	68 3.0	11 2.4	201
	Washington Pass Chert	19 0.7	4 1.4	7 0.5	4 0.6	212 2.1	1589 21.1	430 18.9	31 6.9	2296
	Zuni Wood	1 0.0	0 0.0	2 0.2	1 0.1	15 0.1	209 2.8	26 1.1	0 0.0	254
	Obsidian	88 3.1	22 7.6	20 1.5	7 1.0	86 0.8	29 0.4	167 7.3	9 2.0	428
LOCAL MATERIAL	High Surface Chert	963 34.1	58 20.1	227 17.2	66 9.6	876 8.6	433 5.8	224 9.8	66 14.7	2913
	Cherty Silicified Wood	314 11.1	37 12.8	308 23.4	297 43.4	3336 32.8	1249 16.6	321 14.1	38 8.4	5900
	Splintery Silicif. Wd.	79 2.8	27 9.4	60 4.6	44 6.4	735 7.2	1320 17.6	192 8.4	14 3.1	2471
	Chalcedonic Silicif. Wd.	821 29.1	90 31.3	504 38.3	184 26.9	3410 33.6	865 11.5	377 16.6	153 34.0	6404
	Quartzite	142 5.0	8 2.8	32 2.4	15 2.2	290 2.9	524 7.0	77 3.4	14 3.1	1102
	Other	356 12.6	39 13.5	157 11.9	61 8.9	1129 11.1	907 12.1	335 14.7	110 24.4	3094
	Total	2821	288	1326	684	10158	7519	2276	450	25,522

Chalcedonic Silicified Wood increased in frequency during the late A.D. 900s and early 1000s. It was frequently used for small drills and has been found in association with turquoise production and bead manufacturing areas (Mathien 1981).

Exotic Materials

Location

Five exotic materials have been identified in the Chaco collections (Table 1); however, two of these exotics will not be considered in the following sections: Zuni Wood is considered a low frequency exotic as over one-third of these flakes were found in one pit; obsidian is discussed elsewhere (Cameron and Sappington this volume). The other three exotic materials (Figure 2) are: (1) cherts and quartzitic sandstones of the Brushy Basin member of the Morrison Formation, (2) Yellow-Brown Spotted Chert, and (3) Washington Pass Chert.

While the location for Washington Pass Chert shown in Figure 2 is specific, locations for Morrison Formation materials and Yellow-Brown Spotted Chert are approximate. Usable outcrops of Morrison Formation material have been reported only in the Four Corners area (Phil Shelley, personal communication); however, the Morrison Formation does outcrop at many other locations around the San Juan Basin. Occurrences of Yellow-Brown Spotted Chert have only been reported for the area shown in Figure 2, but other outcrops are possible.

Change Through Time

These three materials are always present in small quantities at sites in Chaco; however, over time their frequencies increase (Table 1). Figure 3 shows the frequencies of these exotic materials from A.D. 800 to 1100. Washington Pass Chert increases from one percent of the assemblage in the A.D. 800s to over 20% in the 1000s and then decreases. Morrison Formation materials follow the same general pattern, although its quantity is never as great as Washington Pass Chert. Yellow-Brown Spotted Chert peaks in frequency later than the other two exotics.

Functional Variation

The ratio of debitage to tools of exotic material suggests that access to some of the sources changed over time. Figure 4 plots the ratio of debitage to tools from A.D. 500 to 1100. A high ratio indicates many flakes per tool, while a low ratio indicates few flakes per tool. During early time periods, exotic materials appear mainly as finished tools and very few flakes of these materials were found. By the A.D. 1000s, however, exotic material appears primarily as bulk chipped stone: cores, debitage, and utilized flakes. This trend suggests either increasingly direct access to the source areas or increasing control over trade with these regions.

The major anomaly in this curve is the earliest period, from A.D. 500 to 600. However, the data for this period were primarily from one unusual provenience at one site (29SJ423) and are probably not representative of lithic trends as a whole.

Chipped Stone In A Regional Perspective

Introduction

Chaco Canyon functioned as part of a larger region; however, the role Chaco played within that region has not been clearly defined. The most common hypothesis suggests that Chaco played a central role in a regional exchange system (Judge 1979; Schelberg 1980; Tainter and Gillio 1980). Alternatively, seasonal aggregation of surrounding populations in Chaco has also been suggested (Loose and Lyons 1976; Windes 1982).

Chipped stone raw material is useful for examining these questions, as its origin can often be accurately pinpointed. However, the mechanics of chipped stone material acquisition, production, and distribution are more difficult to analyze. The following topics examine five areas that may shed light on the various hypotheses: (1) regional patterns of raw material acquisition, (2) volume of exotic chipped stone material, (3) differential consumption of chipped stone at towns and villages, (4) differential access to exotic material at towns and villages, (5) evidence for craft spe-

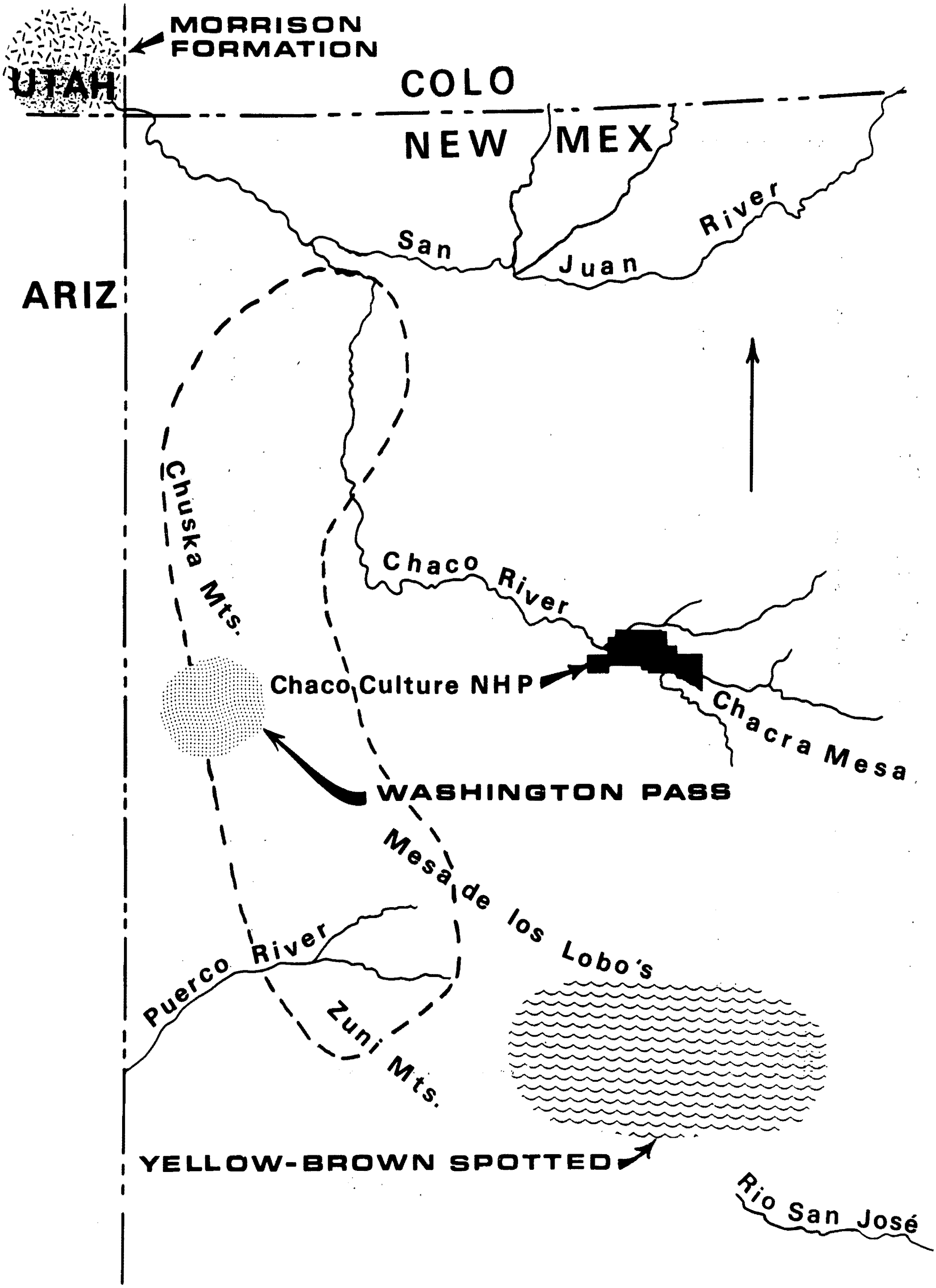

Figure 2. Sources of exotic chipped stone.

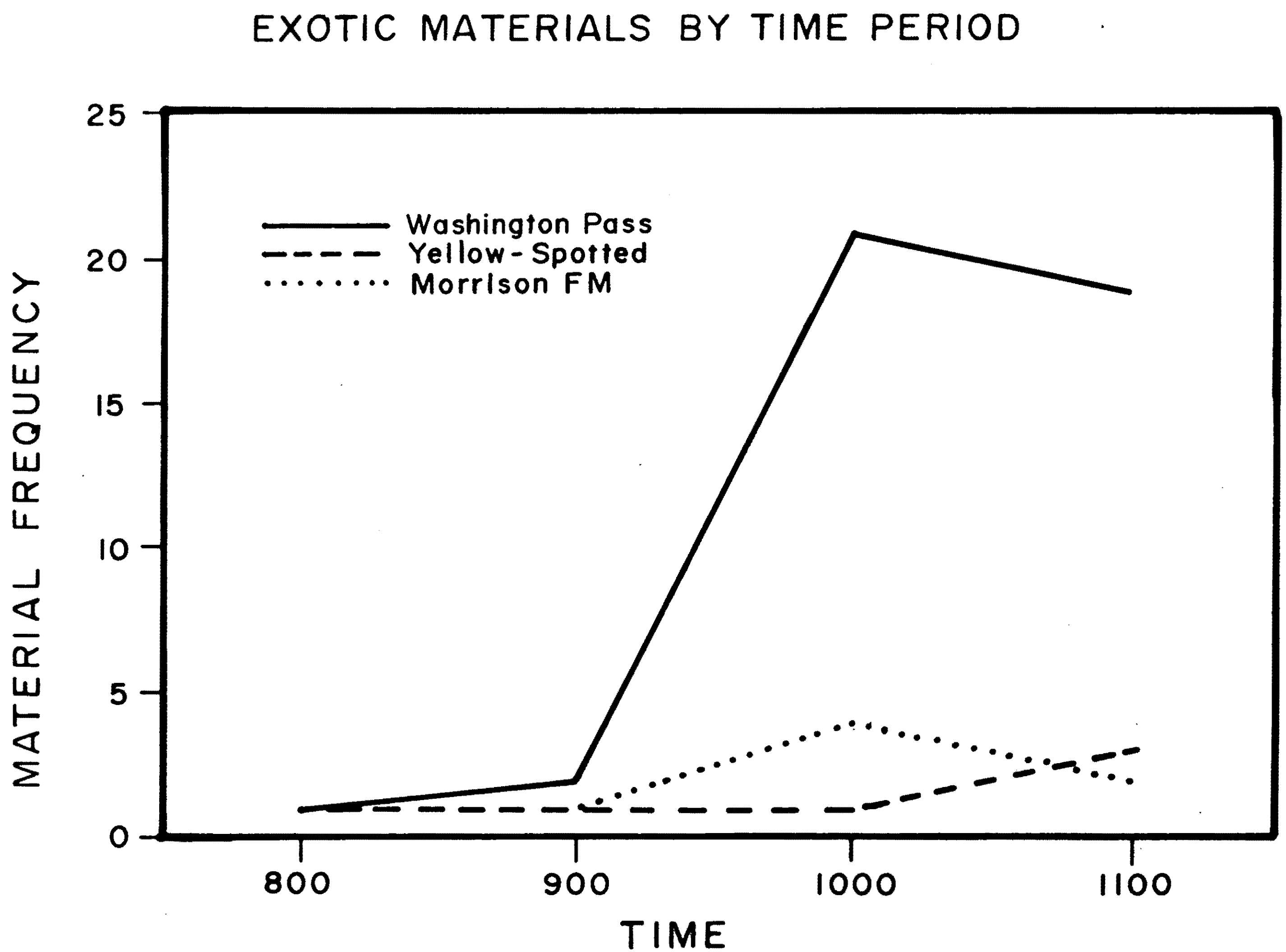

Figure 3. Exotic materials by time period.

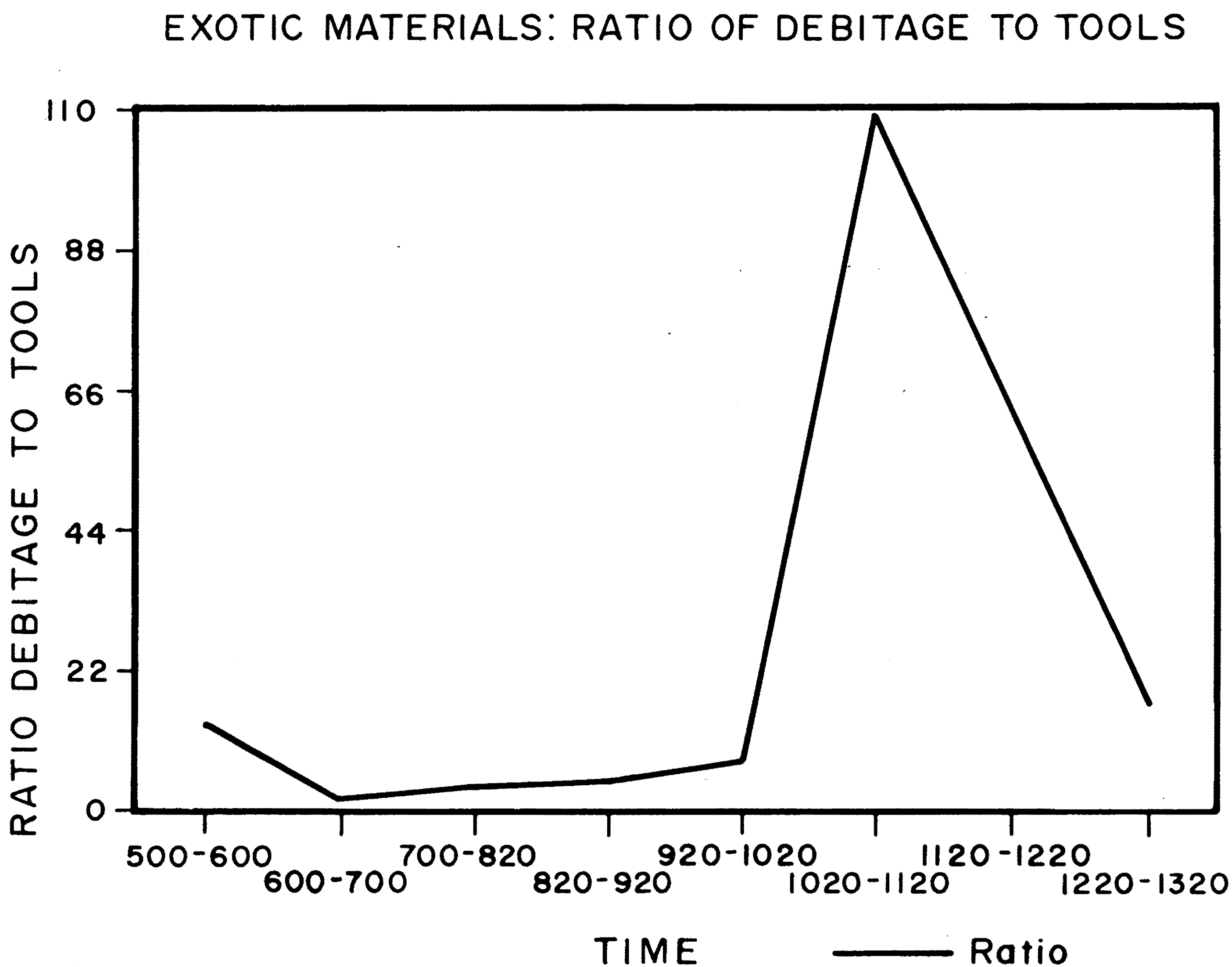

Figure 4. Exotic materials: Ratio of debitage to tools.

cialization in chipped stone manufacture.

The temporal framework developed for the analysis of all artifacts consisted of eight intervals of approximately 100 years each, ranging from A.D. 500 to 1320. The following section deals primarily with the 100-year period from A.D. 1020 to 1120, a period defined by the presence of Gallup-phase ceramics. Chipped stone from this period came primarily from Pueblo Alto and one village site, 29SJ627. The following discussion is complicated by the fact that material from Pueblo Alto probably dates to a span of only 50 years, from A.D. 1050 to 1100, and while it was included in the analytical period A.D. 1020-1120, the specific dates for the Pueblo Alto assemblages (A.D. 1050-1100) will be used.

Regional Patterns

With the exception of relatively few pieces of obsidian, the sources for exotic chipped stone are located less than 150 km from Chaco Canyon. Two hundred kilometers has been described by Renfrew (1977) as the "supply zone" with "a pattern arising largely from single journeys" (ibid., p. 84). The use of fall-off curves to infer modes of exchange may not be appropriate at these short distances. However, fall-off curves can be used to examine the patterns of contact with other areas and to evaluate differential access to resources.

In order to examine the role of Chaco Canyon as a central place in a regional exchange system, chipped stone raw material frequencies from other sites in the San Juan Basin were examined. The information from these sites was gathered by Louann Jacobsen (n.d.) and Robert Powers (Powers and others 1983).

Relative frequencies of Washington Pass chert were plotted for clusters of sites at increasing distance from the source (Figure 5) with percentages and distance converted to a logarithmic scale to increase linearity. A regression line fitted to this curve is significant at the 0.001 level with a correlation coefficient of .86. The frequencies of Washington Pass Chert at Chaco in Pueblo II (10%) and Pueblo III (20%) are remarkably higher than the 1% that would have been expected by linear fall-off. Examination of chipped stone on the surfaces of trash mounds at other towns in the canyon (such as Pueblo Bonito and Chetro Ketl) showed frequencies of Washington Pass Chert as high as 50%, although other exotics were sparse (Windes and Cameron 1980-1981).

The other two exotic materials, Yellow-Brown Spotted Chert and Morrison Formation materials, did not show an abnormally high frequency in Chaco Canyon when compared to a linear fall-off from the source. However, examination of specific proveniences provides slightly different results, especially at towns. For example, trash deposits from Pueblo Alto produced much higher frequencies of Morrison Formation material and Yellow-Brown Spotted chert than the rest of the canyon.

The high frequency of these exotic materials, especially Washington Pass Chert, supports the hypothesis that Chaco Canyon may have played a central role in an exchange system. Some have suggested the system was redistributive. However, Jacobsen's study supports this redistributive system only for the area immediately around Chaco and not for the entire outlier system. Her conclusions are supported by Figure 5. The points above the uppermost confidence band represent outliers close to Chaco.

Quantity Of Imported Chipped Stone Material

Washington Pass Chert comprised 27% of the chipped stone assemblage at Pueblo Alto from A.D. 1050 to 1100, the highest exotic material percentage at any excavated site during any period. An estimate of the total quantity of Washington Pass Chert imported during this period was calculated from the weight of the excavated material and the percentage of the site dug. The resulting figure was approximately 130 kg. Other types of exotic chipped stone material at Pueblo Alto and other excavated Chaco Canyon sites were even lower in total quantity.

Renfrew and others have suggested, with reference to Near Eastern obsidian sources, that small quantities of imported material (under 200 kg) do not necessarily imply a well-organized trading system (Renfrew and others 1968:330). However, assuming that chipped stone material was transported to Chaco in the

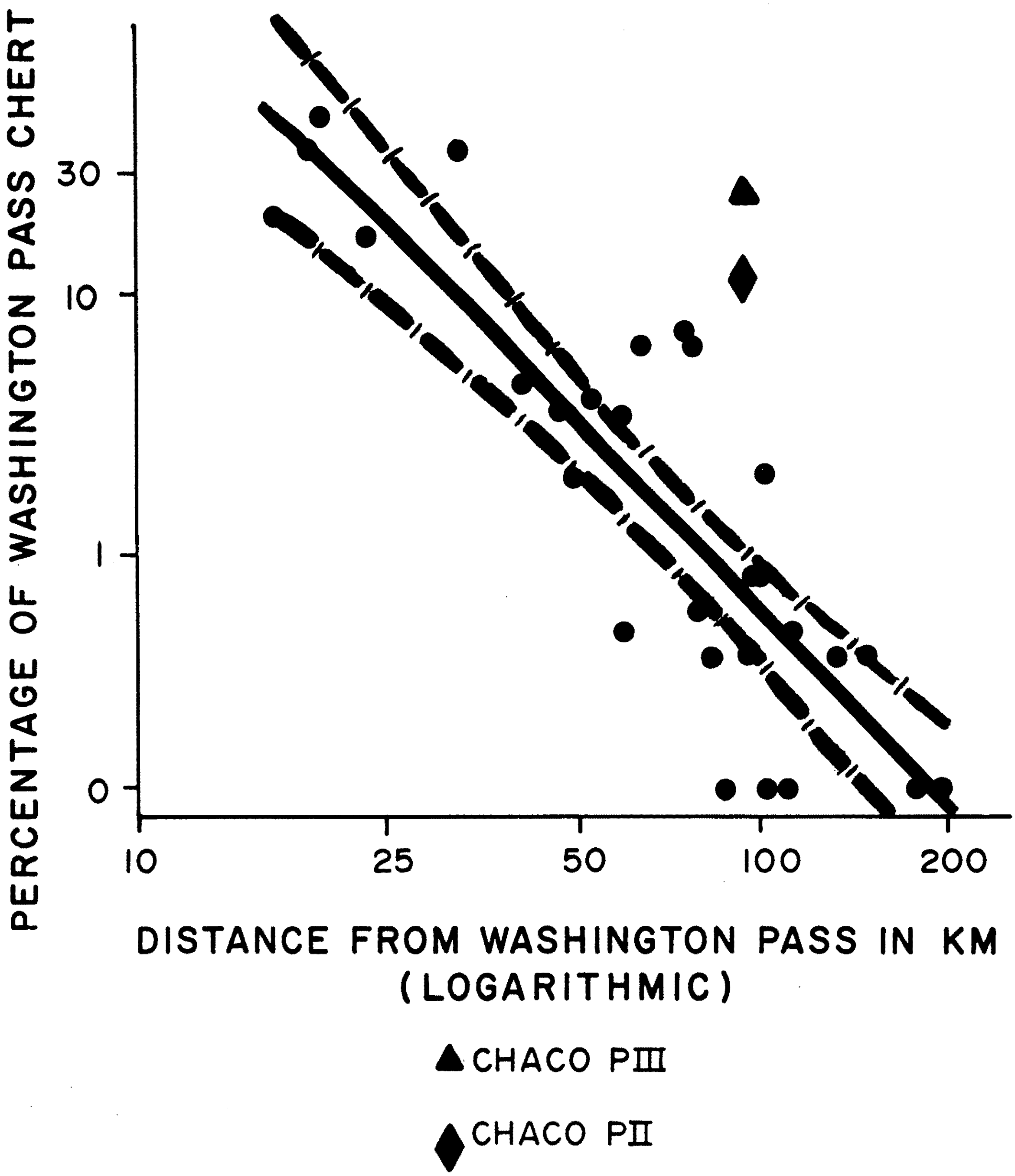

Figure 5. Fall-off of Washington Pass chert.

most expedient way possible, the amount of contact with the source area can be calculated. Following Tourtellot (1978), the number of "carrier days" was estimated for Washington Pass Chert at Pueblo Alto based on the estimated total mass of material imported, distance to source, and an average maximum work rate for foot porters (45 kg x 20 km per day). The calculations were as follows:

$$\frac{\text{Mass x Distance}}{\text{45 kg x 20 km}} = \text{Carrier Days}$$

$$\frac{\text{130 kg x 80 km}}{\text{45 kg x 20 km}} = 11.6$$

Assuming a four-day, one-way trip (20 km per day), less than three trips would have been necessary for the efficient transport of this amount of material from the source.

However, Pueblo Alto is only 1 of 10 large town sites found in Chaco Canyon. As noted previously, Washington Pass Chert frequencies at some of these other sites could be as high as 50%. But, even doubling the number of trips to six and multiplying by 10 sites still results in only 1.2 trips per year during the 50-year period.

This low volume of import can be compared to import volumes for other artifacts. An estimated 49,270 pots may have been imported from the Chuska Mountains area to Pueblo Alto alone from A.D. 1040 to 1100 (Wolky Toll, personal communication). Preliminary estimates for Bonito phase sites indicate that over 150,000 architectural beams may also have been imported during this period (Lekson this volume).

Consumption Of Chipped Stone

The quantity of chipped stone discarded at a site per household per year was calculated (Table 2). The number of households (defined architecturally), duration of occupation and percent of site excavated, were provided by site excavators (Tom Windes and Marcia Truell, personal communication). For example, at Site 29SJ627 an estimated three households occupied the site for 225 years. The volume of chipped stone recovered archaeologically represents an estimated 90% of the chipped stone from the room block (and associated features) and 10% of the chipped stone from the trash mound.

There was much higher use-per-household for Pueblo Alto from A.D. 1050 to 1100 than for village sites in any period. The quantities involved are small; 1.0 kg per household per year for the town site; 0.2 kg for small sites. This would mean that the use-rate for chipped stone at Pueblo Alto is five times as great as that at the village sites.

To cross-check the lithic figures, the same calculations were made for ceramic data (Wolky Toll, personal communication). Site 29SJ629, a village site, averaged eight pots per household per year; Site 29SJ627, a village site, averaged 28 pots per household per year; Pueblo Alto averaged 102 pots per household per year. The number of pots used per household per year is considerably higher for Pueblo Alto. Averaging the number of pots at villages as 18 per household per year, the use-rate at Pueblo Alto is 5.7 times as great as that at the village sites. These figures are comparable to those estimated for chipped stone.

Absolute and relative dating support an approximately 50-year span for the period dominated by Gallup ceramics. The occupants of the large sites were either using chipped stone at a far greater rate than those at the small sites, or there are actually far more people at large sites than are suggested by architectural data alone.

Towns And Villages

At Pueblo Alto from A.D. 1050 to 1100, the frequency of Washington Pass Chert reaches a peak of 27%, whereas in the smaller village sites it reaches its peak of only 7% almost a hundred years later (Table 3). While Morrison Formation materials form less than 5% of the total assemblage, over four-fifths of this exotic import was found at Pueblo Alto, and it was very sparse in the village sites. Yellow-Brown Spotted Chert is different. It forms a higher percentage of the assemblage at villages than it does at towns, and as mentioned previously, it peaked in frequency later

Table 2. Volume of chipped stone used per household per year.

Site	No. Households	Years Occupied	Volume of Chipped Stone/ Household/Year (grams)
29SJ389 (AD 1050-1100)	20	50	922.0
29SJ627 (not Kiva E)	3	225	161.3
29SJ629	2	130	166.2
29SJ633	3	30	222.8
29SJ724	2	20	375.3

Table 3. Frequency of material for towns and villages.

	920 - 1020		1020 - 1120		1120 - 1220	
	Towns	Villages	Towns	Villages	Towns	Villages
Morrison Fm.	8 0.6	32 0.4	319 5.4	8 0.5	59 2.7	0 0
Yellow-Brown Chert	1 0.1	30 0.3	36 0.6	31 1.9	65 3.0	3 4.1
Washington Pass	95 6.8	117 1.3	1525 26.0	64 3.9	424 19.3	5 6.8
Zuni Wood	8 0.6	7 0.1	208 3.5	2 0.1	27 1.2	0 0
Obsidian	12 0.9	74 0.8	14 0.2	15 0.9	167 7.6	0 0
High Surface Cherts	127 9.2	749 8.5	269 4.6	166 10.0	212 9.6	12 16.2
Cherty Silicified Wood	284 20.5	3049 34.8	585 10.0	664 40.0	315 14.3	7 9.5
Splintery Silicified Wood	40 2.9	695 7.9	1196 20.4	124 7.5	189 8.6	3 4.1
Chalcedonic Silicified Wood	488 35.2	2921 33.3	487 8.3	374 22.6	353 16.0	24 32.4
Quartzite	64 4.6	226 2.6	494 8.4	30 1.8	74 3.4	3 4.1
Other	260 18.7	868 9.9	728 12.4	180 10.9	317 14.4	17 23.0
Total	1387	8768	5861	1658	2202	74

than did Washington Pass Chert and Morrison Formation materials.

However, the comparison of towns and villages presumes contemporary samples from each site type. While proveniences from both towns and villages do fall into the same 100-year spans, they may not be fully contemporaneous within these intervals. The period from A.D. 1050 to 1100 is of most interest, as this period saw the highest frequencies of exotic materials, and it appears that exotic material was obtained preferentially at town sites.

The village sites within the period A.D. 1020 to 1120 may be earlier than the excavated town sites assigned to this span. Almost all material from this period is from Pueblo Alto and 29SJ627. For the most part, 29SJ627 dates no later than A.D. 1040 (Marcia Truell, personal communication). Trash from Kiva E at 29SJ627 contains later material, but Truell feels that these deposits are too mixed to be clearly comparable to material at Pueblo Alto. Thus, there may be little well-dated excavated village material from A.D. 1050-1100, the period of greatest activity at town sites.

Some small sites in Chaco may have received Washington Pass Chert in relative frequencies similar to those of the large sites. Ceramic data from BC362 (Voll 1964) indicate that this site is contemporaneous with the Classic Bonito Phase at the large sites (Tom Windes, personal communication). A sample (n=411) of unprovenienced chipped stone from this site included 23% Washington Pass Chert, a frequency similar to that found at Pueblo Alto in presumably contemporaneous deposits.

Surface material on the trash mound of an unexcavated village site (29SJ839) was examined (Tom Windes, personal communication) and ceramic data indicated that it could be placed within the period from A.D. 1050 to 1100. A transect across the trash mound identified 15% Washington Pass Chert, much higher than the percentage of this material found at any recently excavated village site.

Based on presently excavated sites, evidence of differential access to exotic material at towns and villages is ambiguous. The scant evidence of BC362 and 29SJ839 suggests that Washington Pass Chert may have occurred in similar relative frequencies at both towns and villages from A.D. 1050 to 1100. Ceramic evidence supports this conclusion. Ceramic imports from the Chuska Mountains (where Washington Pass is located) are very similar in relative frequency at both Pueblo Alto and 29SJ627 during the period A.D. 1020-1120 (Wolky Toll, personal communication).

Evidence For Craft Specialization

Specialized production might be suggested archaeologically by increasing standardization of techniques and forms, increasing the <u>number</u> of standardized forms, increasingly specific selection of raw materials, and localized production areas (Rice 1981; Toll 1981; Torrance 1981). Specialized production of certain chipped stone tools has been suggested for Salmon Ruin, a Chacoan site on the San Juan River (Shelley 1980).

A total of only 500 formal chipped stone tools (with a range in dates from A.D. 500 to 1320) were recovered from excavated sites. While there are stylistic changes over time in projectile point types (from stemmed- to corner- to side-notched), there does not seem to be an increasing number of standardized types (Lekson n.d.).

However, several very unusual tools were recovered at Pueblo Bonito in earlier excavations (Judd 1954). The artifacts include a number of very large bifaces and 28 stylistically and technologically unusual projectile points associated with a burial (Room 330, Burial 10). These tools indicate the presence of skilled craftsmen (Bradley 1979).

Flake attributes did not suggest an increasingly standardized technology as would be indicated by regularity in flake size or special treatment of cores (Cameron 1982). Mean flake sizes did not change through time nor did standard deviations. The incidence of prepared platforms on flakes did not increase over time.

Although an increasing frequency of regular core types might indicate increasingly standardized technology, cores in Chaco show no such temporal patterning (Cameron 1982). Bradley (1979) states that the primary technology is "mainly a highly opportunistic flake production..." but that "a great range of craftsmanship is exhibited...." This range in craftsmanship has not been related to temporal trends that could support the development of craft specialization.

The best argument for the selection of specific material for chipped stone production could be made for Washington Pass Chert from A.D. 1050 to 1100. However, there is little evidence to indicate that Washington Pass Chert was treated any differently than local material. Of the 60 cores recovered from the Pueblo Alto Trash Mound, eight were discoidal, the main regularized form. Of these, half (n=4) were Washington Pass. This suggests formalization of Washington Pass cores. However, contrasting discoidal cores and all other core types, and Washington Pass Chert and all other material types, the resulting chi-square was not significant at the 0.05 level (DF=1, X^2=2.84, 0.5<P<.1). Tools of Washington Pass Chert are infrequent in the canyon (n=15, 3.2% of the tool collection), and there is no evidence of quantities of Washington Pass Chert tools elsewhere in the Chacoan region. This argues against specialized production of tools of this material type for use at other canyon sites or at sites outside the canyon.

Obsidian tools constitute almost one fifth (18%) of all excavated tools. But, except for the period from A.D. 1120 to 1220, obsidian flakes are rare. This suggests the import of finished tools, rather than raw material, into the canyon and production of these tools at some location other than Chaco. An area of specialized production of obsidian tools has been suggested for the Baca Locality in the Jemez Mountains (Winter 1981).

There is little evidence for specialized production of chipped stone tools in Chaco Canyon, and there seems to be no evidence that exotic material was imported for this purpose.

Conclusions

Analysis of chipped stone in Chaco Canyon emphasized identification of raw material sources. Patterned variability was noted in both the selection of raw material types and in the functions of some local materials. Perhaps the most significant result of the analysis was the documentation of temporal variability in the import of exotic chipped stone. These data have been used to examine the role of Chaco Canyon within a regional exchange system.

The redistribution of chipped stone from Chaco Canyon was not clearly supported by the results of this study. The most frequent exotic was Washington Pass Chert; Chaco Canyon received greater quantities of this material than would have been expected by linear fall-off. However, redistribution of Washington Pass Chert to surrounding outliers was indicated only for the few outliers immediately around Chaco. The total quantity of Washington Pass Chert that was imported into the canyon does not indicate large-scale trade or acquisition, certainly not comparable to that for ceramics or architectural beams. Additionally, there was no evidence to indicate that Washington Pass Chert was imported for manufacture into a particular tool type. There was little or no evidence of craft specialization in the production of chipped stone tools or of the selection of exotic material for specific tool types.

The hypothesis of periodic aggregation of the surrounding population found some support in the chipped stone data. The quantities of chipped stone recovered from the Pueblo Alto trash mound suggested a population far greater than would be indicated by architecture alone. If the acquisition of chipped stone raw material were part of an "embedded procurement strategy" (Binford 1979) in which it was acquired only incidentally during the acquisition of other types of goods, then this might explain the presence of exotic chipped stone material at sites in Chaco Canyon and its relatively low total volume.

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OBSIDIAN PROCUREMENT AT CHACO CANYON, A.D. 500-1200

Catherine M. Cameron and Robert Lee Sappington

Abstract

Obsidian has been found in small quantities at nearly all excavated sites in Chaco Canyon. X-ray fluorescence has been used to correlate obsidian artifacts to 12 distinct sources located in New Mexico, Arizona, Colorado and Utah. A majority of the obsidian originates from two New Mexico sources: Jemez and Red Hill. A temporal shift in the use of these two sources is observed. An examination of methods of obsidian acquisition indicates that obsidian was not a major part of the regional exchange system that has been proposed for other artifacts in Chaco Canyon, but was more likely part of a less formalized mechanism of exchange.

Introduction

Importance Of Sourcing Studies

Obsidian artifacts have been recovered from all temporal periods and from nearly all sites tested or excavated at Chaco Canyon. The igneous origin of obsidian makes it ideal for trace element studies because each flow represents a unique geological event and therefore possesses a distinctive chemical "fingerprint." Several geochemical techniques are available for characterizing sources, but x-ray fluorescence is probably the most popular for researchers across western North America, especially in California and the Great Basin (Jack and Carmichael 1969; Jackson 1974; Ericson and others 1976; Jack 1976; Hughes 1978; Nelson and Holmes 1979; Sappington 1981).

A number of obsidian source areas exist in the American Southwest (Figure 1), but none are within 100 km of Chaco Canyon. Previous studies have shown that the inhabitants of the canyon were involved in a wide-ranging regional economy that included the importation of commodities as diverse as turquoise, copper, pottery, and even macaws from central Mexico (Judd 1954; Mathien 1981). Therefore, the determination of the origin of obsidian found in Chaco Canyon could be expected to add another dimension to the placement of Chaco within a regional exchange system.

Brief Overview Of Chaco Canyon

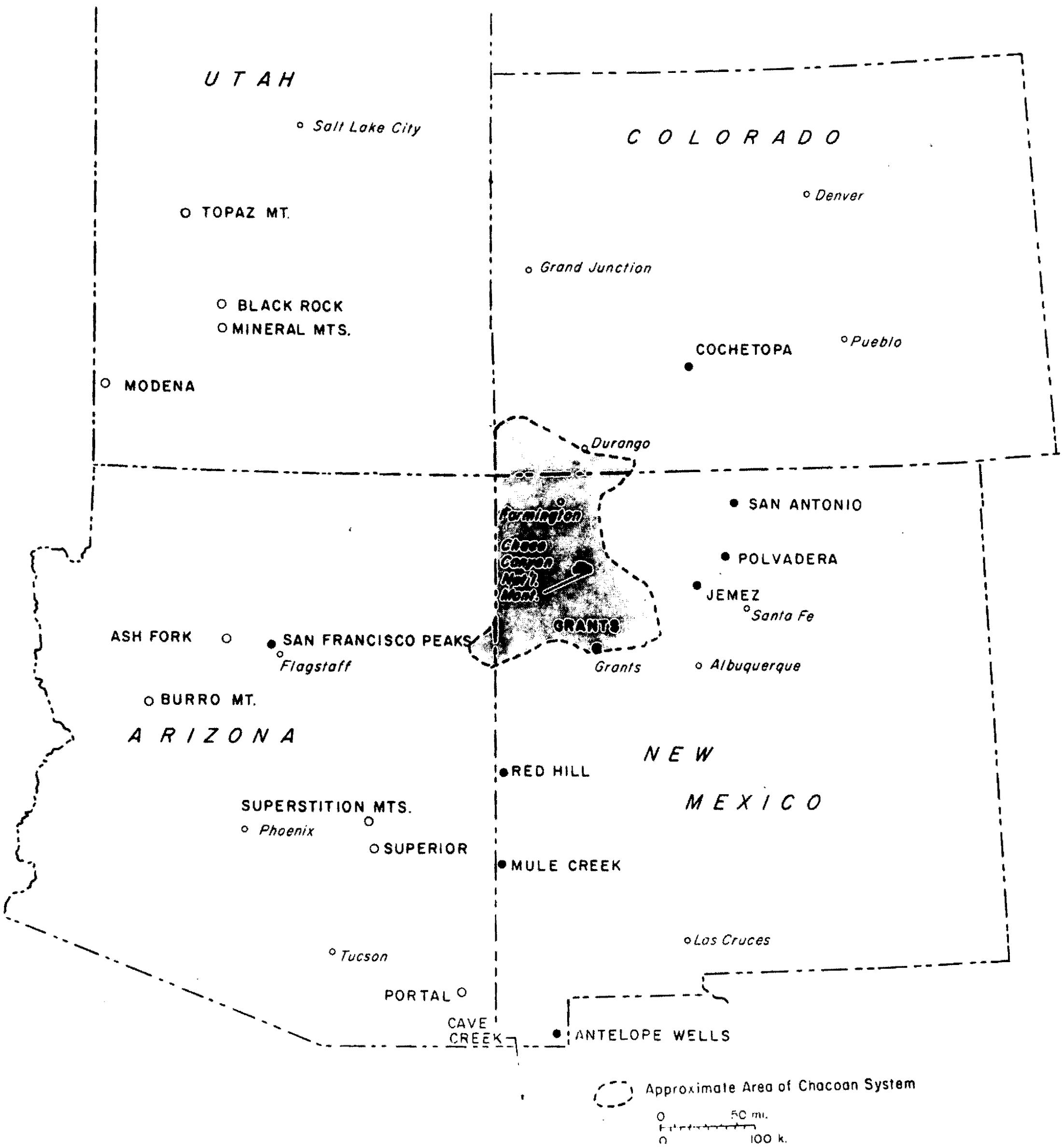
Chaco Canyon, located in the San Juan Basin of northwestern New Mexico, was intensively occupied during the Anasazi period A.D. 500-1300. Beginning about A.D. 900, the canyon was the setting of a complex social and economic system characterized by large, planned architectural structures in the canyon and a larger regional system of related sites (Powers this volume). Extensive trade within this region has been documented with both ceramic (Toll 1980) and chipped stone (Cameron 1982) evidence. Current interpretations (Judge 1979) place Chaco at the center of a region-wide exchange network.

Concurrent with the occupation of the large planned sites, smaller sites (similar to Anasazi sites outside the canyon) were also in use. The large sites have been termed "towns" and the smaller sites "villages." There is evidence of differential access to imported goods at these sites (Toll and others 1980; Cameron 1982).

The Nature Of The Obsidian Sample

Recently, 16 sites were excavated or tested in Chaco Canyon by the Chaco Center, National Park Service. These sites sample the full temporal range of the Anasazi period and include both towns and villages. Obsidian from these sites was not abundant. From over 34,000 pieces of chipped stone, 665 (2%) were obsidian. Of this total of excavated obsidian, 626 pieces were analyzed to determine source area (39 pieces were unavailable for analysis). This sample was then increased to 665 items by the inclusion of obsidian from previously excavated sites in Chaco, including a number of projectile points from Pueblo Bonito (Table 1).

Figure 1. Southwestern obsidian sources used for comparison with the Chaco sample.



U T A H
Salt Lake City
TOPAZ MT.
BLACK ROCK
MINERAL MTS.
MODENA
C O L O R A D O
Denver
Grand Junction
COCHETOPA
Pueblo
Durango
SAN ANTONIO
POLVADERA
JEMEZ
Santa Fe
GRANTS
Grants
Albuquerque
ASH FORK
SAN FRANCISCO PEAKS
Flagstaff
BURRO MT.
A R I Z O N A
N E W
M E X I C O
RED HILL
SUPERSTITION MTS.
Phoenix
SUPERIOR
MULE CREEK
Los Cruces
Tucson
PORTAL
CAVE
CREEK
ANTELOPE WELLS
Approximate Area of Chacoan System
0
50 mi.
0
100 k.

Table 1. XRF source assignments by site.

Site	Time-Period	Total Obsidian	XRF Analy.	XRF Assigned Source	Freq.
MC184	750- 850	1	1	Modena, UT.	1
29SJ299	610- 690	8	8	Jemez, NM	3
	790- 820			Red Hill, NM	2
	910- 930			Sitgreaves Peak, AZ	1
	1190-1220			Unknown	2
Pueblo Alto	980-1150	348	328	Jemez, NM	269
				Grants, NM	1
				Polvadera, NM	18
				Red Hill, NM	8
				Government Mt., AZ	9
				San Antonio Peak, NM	2
				Superior, AZ	1
				Mule Creek, NM	6
				Sitgreaves Peak, AZ	8
				Mineral Mts., UT	1
				Modena, UT	1
				Unknown	4
				Jemez, NM	1
Una Vida	930-1150/ 1250	1	1	Cochetopa, CO	1
29SJ423	510- 620	88	90	Jemez, NM	1
				Grants, NM	4
				Polvadera, NM	7
				Red Hill, NM	61
				Sitgreaves Peak, AZ	3
				Mineral Mts., UT	10
				Modena, UT	1
				Unknown	2
29SJ626	PI - PII	3	3	Jemez, NM	3
29SJ627	770-1140	75	68	Jemez, NM	33
				Grants, NM	4
				Polvadera, NM	6
				Red Hill, NM	21
				Superior, AZ	1
				Mule Creek, NM	1
				Mineral Mts., UT	2
29SJ628	600- 830	47	38	Jemez, NM	14
				Grants, NM	4
				Polvadera, NM	1
				Red Hill, NM	14
				San Antonio Peak, NM	2
				Mineral Mt., UT	1
				Unknown	2
29SJ629	875/900-1030	39	35	Jemez, NM	15
	1100-1140			Polvadera, NM	4
				Red Hill, NM	11
				Sitgreaves Peak, AZ	2
				Mineral Mts., UT	1
				Unknown	2
29SJ633	1150-1250	10	10	Jemez, NM	8
				Red Hill, NM	2

Table 1 (continued).

29SJ721	660- 730	1	1	Red Hill,NM	1
29SJ724	780- 800	16	15	Cochetopa,CO	1
	800- 900			Jemez,NM	7
				Grants,NM	2
				Polvadera,NM	1
				Red Hill,NM	3
				Mule Creek,NM	1
29SJ1360	820-1020	14	12	Jemez,NM	7
				Polvadera,NM	4
				Red Hill,NM	1
29SJ1659	510- 710	16	13	Jemez,NM	1
				Polvadera,NM	2
				Red Hill,NM	6
				Superior,AZ	1
				Sitgreaves Peak,AZ	1
				Mineral Mts.,UT	2
29SJ1156	Archaic	?	3	Jemez,NM	3
BC51	PIII	?	2	Jemez,NM	1
				Mule Creek,NM	1
BC59	PIII	?	1	Jemez,NM	1
Kin Kletso	1100's	?	5	Jemez,NM	3
				Mineral Mts.,UT	2
Talus Unit	1100's	?	2	Polvadera,NM	2
Pueblo del Arroyo	1040/1150-1250	?	2	Jemez,NM	1
				Grants,NM	1
Pueblo Bonito	900-1130	?	25	Jemez,NM	14
				Polvadera,NM	7
				Red Hill,NM	2
				Government Mt.,AZ	1
				Unknown	1
Stone Circles	1000-1100	?	2	Jemez,NM	1
				Polvadera,NM	1
Hosta Butte	PIII/Hist.	?	1	Jemez,NM	1

Procedures

The Chaco Canyon sample was analyzed by nondestructive, energy dispersive x-ray fluorescence at the facilities of the Idaho Bureau of Mines and Geology. The system employed for this analysis consists of a Tracor Northern NS-880 instrument, with a Nuclear Semiconductor 512 amplifier, a silicon (lithium-drifted) detector with a New England Nuclear americium-241 100 millicurie source and a dysprosium secondary target, attached to a PDP 11/05 computer and a Decwriter II printer. All items were analyzed in air for a 300-second counting period. The intensities of 10 trace elements--Fe, Rb, Sr, Y, Zr, Nb, Sn, Ba, La, and Ce--were recorded and employed as the variables for SPSS discriminant analysis using the MAHAL stepwise method (Nie and others 1975). Discriminant analysis is a multivariate statistical technique focused on discovering and emphasizing those attributes that best distinguish between predetermined groups of cases, such as samples from obsidian sources. The MAHAL method was selected because it combines and recombines the variables in all possible combinations and then ranks them by their ability to differentiate between the two closest groups.

Prerequisite for the correlation of the Chaco Canyon samples with their source areas was the characterization of all potential sources. Twenty-four distinct obsidian source areas were chemically characterized and described in New Mexico, Arizona, Utah, Colorado, and Mexico (Table 2). For most sources at least 20 individual pieces were analyzed. The discriminant program provides a means for determining the reliability of the source groups by the use of the F statistic (Table 3). F statistics for all 300 pairs of sources indicate that the difference for all but 12 pairs is meaningful at the .05 level; in addition, all but 17 pairs exhibit significant differences at the .01 level. Virtually all of the overlapping sources are located in the San Francisco Mountains in north-central Arizona. The failure to differentiate between these sources may be (1) because the few samples analyzed do not adequately characterize the chemistry of these sources, and/or (2) there is no chemical distinction among all these sources, at least that can be determined by this system. There are also too few samples from the Modena source of southwestern Utah, and it overlaps with three other sources; the correlation of Chaco Canyon specimens to that source should probably be regarded as tenuous, at least until additional nodules can be obtained.

Classification results for the grouped cases (Table 4) indicate the reliability of the individual items within the 24 groups. Overall, 96% of the 393 source items were correctly classified; that is, they apparently "belong" to their assigned groups. Cases in 18 source groups are 100% correctly assigned, while the remainder vary from having a single item misclassified to the Red Hill source, which has 22% of its population assigned to other sources. Apparently, it is not possible to completely distinguish the Red Hill source by this suite of elements.

The Chaco Canyon artifacts were run as ungrouped items and assigned to their two most likely source groups based on their discriminant scores. Because the program is designed so that all ungrouped cases <u>must</u> be assigned to a source group, it is possible that some artifacts may have been matched to an incorrect source because the true source was not included in the comparative base. Therefore, those items assigned to their most likely source group [P(G/X)] with a probability outside of one standard deviation (>.6800) are regarded as unknown. Overall, 654 (98%) of the 665 Chaco Canyon artifacts were correlated to a total of 12 sources with acceptable probabilities.

<u>Temporal Variation</u>

Introduction

Obsidian found at sites in Chaco Canyon originated from at least 12 distinct sources. Over 50% of the obsidian has been identified as Jemez and 25% as Red Hill; no other source exceeds 10%.

Table 5 shows the frequency of each type of obsidian by time period (using only excavated material with accurate temporal assignments). Of the less frequent sources, those originating in Utah seem to occur most often in the early time periods, while other low frequency material is more scattered throughout all time periods. Figure 2 graphs the relative frequencies of the three most frequent sources through time with all other sources combined. There appears to be a

Table 2. Source descriptions.

NEW MEXICO

JEMEZ MOUNTAINS - Sandoval and Los Alamos Counties

Obsidian occurs over wide areas of the Jemez Mountains. Obsidian Ridge, between Canyon de los Frijoles and Alamo Canyon has been mapped as part of the Toledo Tuff sequence (Smith and others 1970), an obsidian-bearing stratum that outcrops as far south as the Pajarito Plateau. A large source of artifact grade obsidian is the Valles Caldera on and around Cerro del Medio and its courses. Obsidian also occurs in the older gravels of the Cochiti formation on Borrego Mesa and is associated with the Canovas Canyon Rhyolite in the Bear Springs area (Smith 1978). Samples of Jemez obsidian were obtained from Obsidian Ridge by Judge, Russell, and Baker; from a side drainage near the head of Cochiti Canyon by Russell (T18N, R5E, Section 17); from gravels near the juncture of Bland and Cochiti Canyons (by Russell); and from north of Cerro del Medio (by Baker).

POLVADERA PEAK - Rio Arriba County

Obsidian is found on the north flank of the Jemez Mountains associated with three rhyolite domes (El Recheulos Rhyolite) that lie just west of Polvadera Peak. Gravels derived from these domes carry obsidian cobbles and pebbles that underlie the Bandelier Tuff north and westward from the domes (Smith 1978). Samples were obtained from two areas west of Polvadera Peak by Russell; above El Recheulos drainage and on the mesa east of Polvadera Creek. Schaffsma also collected samples from the lower slopes of the north face of Polvadera Peak.

GRANTS RIDGE - Valencia County

Grants obsidian occurs as clasts within a pumaceous pyroclastic flow exposed on both north and south sides of East Grants Ridge (Thaden and others 1967 cited in Love 1981). Obsidian clasts also occur in gravel deposits downstream from the flow along the Rio San Jose, Rio Puerco and Rio Grande (Love 1982). Samples were selected by Love from several areas along New Mexico Highway 547 near the head of Lobo Canyon (also called Grants Canyon), 7-8 km NE of Grants, NM.

RED HILL - Catron County

Red Hill obsidian occurs as clasts up to 15 cm long in gravels 10 km south of Red Hill, NM (T2S, R19W parts of Sections 7,8,17,19,20). The source of the obsidian-bearing gravels has not been located, but appears to be to the southwest. The gravels appear to underlie and overlie basalt flows in the area (Willard and Weber 1958 cited in Love 1982). Samples were collected by Warren, Love and Cameron from a number of areas within this general location.

SAN ANTONIO PEAK - Taos County

San Antonio Peak obsidian occurs as nodules associated with deposits of perlite. It is located 7 miles north of Tres Piedras in the area between the No Agua Peaks and Cerro del Aire. Samples were collected from perlite mines in this area by Whitsen, a mine geologist.

MULE CREEK - Grant County

Samples of Mule Creek obsidian were collected by Findlow at the town of Mule Creek, northwest of the Mule Mountains, near the corner of T14S, R21W; T14S, R20W; T13S, R20W; T13S, R21W NMPM.

ANTELOPE WELLS - Hidalgo County

Antelope Wells obsidian was collected by Findlow from two widely separated areas. The first is on Deer Creek near the Culbertson Ruin (NW part of T34S, R17W), and the second is on Clanton Draw near the boundary of the Coronado National Forest. Findlow states that these two areas produce chemically identical obsidian (personal communication).

Table 2 (continued).

COLORADO

COCHETOPA - Saguache County

Obsidian was collected from around Cochetopa Dome (T46N, R2E, East 1/2 of Sections 23 and 26) by Stiger. Cochetopa Dome is located 7 miles NW of Cochetopa Pass near Colorado Highway 114.

ARIZONA

SUPERIOR - Pinal County

Obsidian from the Superior source was collected by Findlow from several perlite mines near the town of Superior, Arizona.

SUPERSTITION MOUNTAINS - Pinal County

Samples of Superstition obsidian were obtained by Findlow from several perlite mines in and around the Superstition Mountains about 40 km east of Phoenix, Arizona.

ASH FORK - Coconio County

Obsidian from this source was collected from the Mt. Floyd volcanic field, 25-30 km NE of Ash Fork, Arizona.

CRATER LAKE

Samples were collected from the foot of the eastern slope of Kendrick Peak in colluvial deposits.

BURRO MT.

Samples collected at a point 1.6 km (1 mile) from Burro Creek crossing.

OTHER ARIZONA SOURCES

O'Leary Peak, Sitgreaves Peak, Robinson Crater, Kendrick Peak, Fish-Sawmill, Agassiz-Fremont and Government Mountain are described in Schreiber (1967), Schreiber and Breed (1970), and Jack (1971).

UTAH

The Utah sources, their locations, trace element chemistry and archaeological significance have been reported elsewhere (Nelson and Holmes 1979).

MEXICO

CAVE CREEK - Chihuahua

This source is located near the site of Casas Grandes in northern Mexico. DiPeso and others (1974) give the following location "...within the southwestern provincial border of Casas near present-day Tres Rios on the Gavilan drainage, some 25km (15 mi.) west of the Mormon colony of Pacheco." Samples of this source were obtained by Findlow from museum collections.

Table 2a. Southwestern obsidian sources used for comparison.

SOURCE	#SAMPLES	LOCATION	PROVIDER	USGS 1-250,000
Jemez	20	T18N,R5E	Dr.W.James Judge - Univ. of New Mexico	Albuq., NM
Jemez	20	Baca Location No.1	Craig Baker - OCA Univ. of New Mexico	Albuq.. NM
Jemez	30	T18N,R5E; Canada del Cochiti	Glenn Russell - UCLA	Albuq., NM
Polvadera	10	Polvadera Grant	Glenn Russell - UCLA	Aztec, NM; CO
Polvadera	20	Polvadara Grant	Curtis Schaafsma-Lab. of Anthro.Santa Fe	Aztec, NM; CO
Grants	20	T11N,R9W, R10W	David Love - Bureau of Mines, Socorro, NM	Albuq., NM
Red Hill	27	T2S,R19W	H.Warren et al. - Albuq, NM	St.Johns,AZ NM
San Antonio Peak	20	T29N,R9E	David Whitson - John-Manville Co, San Antonito, Colo.	Raton, NM CO
Mule Creek	31	T14S,R21W;T14S,R20W T13S,R20W;T13S,R21W	Dr. Frank Findlow - Northridge, CA	Clifton,AZ NM
Antelope Wells	23	T34S,R17W T32S,R20W	F. Findlow	Douglas,AZ NM
O'Leary Peak	5	See Schreiber (1967)	Dr. William Breed, Museum of N. Arizona	
Sitgreaves Mt.	5	See Schreiber (1967)	Dr. William Breed Dr. William Breed	
Robinson Crater	5	See Schreiber (1967)	Dr. William Breed	
Kendrick Peak	5	See Schreiber (1967)	Dr. William Breed	
Fish-Sawmill	5	See Schreiber (1967)	Dr. William Breed	
Agassiz-Fremont	5	See Schreiber (1967)	Dr. William Breed	
Government Mt.	5	See Schreiber (1967)	Dr. William Breed	
Government Mt.	5		Dr. Richard Ambler	
Government Mt.	4		Roger A. Moore	
Superior	23	T1S,R12E T2S,R12E	F. Findlow	Mesa, AZ
Superstition Mt.	3	T1N,R9E	F. Findlow	Mesa, AZ.
Ash Fork	5	T23N,R4W	F. Findlow	Williams,AZ
Crater Lake	15	T24N,R5E	F. Findlow	Flagstaff,AZ
Burro Mt.	5	T14N,R11W SE Sec 20	F. Findlow	Prescott,AZ
Cochetopa Dome	20	T46N,R2E	Mark Stieger - Univ. of New Mexico	Montrose,CO
Cave Creek	17	Chihuahua, Mexico	F. Findlow	No Map
School Mine/ Mineral Mts	25	Various locations across T27S R9W and T28S,9W	Dr. Fred W. Nelson, Brigham Young Univ. and Mike Benson, Utah State Historical Soc.	Richfield, Utah
Topaz Mt. Utah	5	T12S, R11W, sects. 28,30,31	Dr. Fred Nelson	Delta,Utah
Modena Utah	2	T35S, R19W, sec. 12	Dr. Fred Nelson	Cedar City, Utah
Black Rock Utah	7	T23S & 24S, R7W, 8W, 9W,10W various locations	Dr. Fred Nelson	Richfield, Utah

Table 3. F-statistics and significances between pairs of source groups

	1	2	3	4	5	6	7	8	9	10	12	15	16	17	18	19	20	21	22	23	26	30	32	33
1. Antelope Wells																								
2. Cochetopa	110.																							
3. Jemez	137.	48.5																						
4. Grants Ridge	305.	77.5	129.																					
5. Polvadera	213.	28.3	47.7	37.9																				
6. Red Hill	240.	47.3	66.9	20.9	12.6																			
7. Government Mt.	224.	90.4	124.	80.4	80.5	65.4																		
8. San Antonio Pk.	232.	47.6	83.2	10.9	20.7	18.2	72.8																	
9. Cave Creek	253.	113.	172.	107.	118.	98.3	5.51	96.7																
10. Superior	270.	113.	182.	110.	120.	103.	13.4	101.	5.39															
12. Mule Creek	154.	18.9	63.0	71.2	38.3	37.9	52.4	44.4	64.4	63.7														
15. Superstition Mts.	79.7	38.3	46.3	37.5	38.2	34.8	10.5	37.3	7.71	5.57	24.7													
16. Ash Fork	120.	54.2	69.1	54.0	53.7	47.5	11.4	53.2	11.9	11.8	36.3	1.41 (.184)												
17. O'Leary Pk.	131.	66.1	86.0	70.2	70.4	65.5	28.9	70.8	28.5	25.3	52.0	2.66 (.005)	2.90 (.003)											
18. Sitgreaves Pk.	110.	35.7	25.5	12.6	11.2	10.0	32.9	13.6	45.9	39.9	29.3	23.0	27.9	36.1										
19. Robinson Crater	137.	71.3	92.5	74.9	76.3	71.3	33.9	76.3	33.0	28.9	57.5	3.25 (.001)	4.35	.178 (.996)	38.7									
20. Kendrick Pk.	129.	61.5	79.4	65.5	64.1	60.7	23.8	64.8	23.2	19.6	47.2	1.67 (.096)	2.44 (.011)	1.17 (.312)	33.0	1.47 (.157)								
21. Fish Sawmill	130.	66.0	85.2	69.1	70.0	65.0	27.4	69.8	25.9	22.2	50.6	1.85 (.059)	2.67 (.005)	.141 (.999)	35.8	.285 (.979)	.848 (.572)							
22. Agassize Fremont	86.1	106.	120.	196.	142.	166.	173.	171.	190.	180.	142.	74.4	94.3	81.5	98.5	81.4	82.7	84.2						
23. Burro Creek	91.3	20.6	40.8	16.2	25.1	17.4	40.3	15.1	45.0	43.5	16.6	25.3	31.8	39.8	23.0	42.5	37.3	39.3	106.					
26. School Mine	185.	25.1	76.5	49.6	37.8	25.6	57.0	33.8	73.9	78.4	10.1	28.9	40.8	57.8	29.5	63.3	52.1	56.7	155.	7.02				
30. Topaz Mts.	76.7	11.4	36.8	18.7	19.5	17.5	42.7	15.0	45.4	42.0	11.5	24.5	31.7	37.9	23.4	40.5	37.1	37.6	95.6	4.45	8.86			
32. Modena	46.7	21.4	23.9	20.1	19.6	16.8	1.44 (.170)	18.5	.79 E-01 (.999)	.849 (.572)	10.4	3.64 (.0002)	4.50	10.5	15.0	12.2	8.81	9.59	70.0	16.0	12.9	15.8		
33. Black Rock	95.3	19.6	39.4	24.4	24.5	16.8	44.6	15.1	52.6	55.4	13.9	32.5	41.4	55.6	27.1	60.1	51.4	54.9	126.	3.77 (.0001)	4.66	6.79	16.0	
40. Crater Lake	122.	36.2	24.0	69.2	23.6	31.6	36.7	51.3	55.2	50.6	26.2	25.9	34.7	50.1	17.0	55.2	42.8	48.9	115.	36.8	37.4	33.8	12.0	35.4

F statistic — number not in parenthesis

Significance -- number in parenthesis. Where no parentheses are evident, significance is zero.

Note: Numbers across the top correspond to numbered locations down left side.

Note: F statistics and significances have been rounded off to facilitate presentation.

Table 4. Classification results of sources and Chaco artifacts.

		Predicted Group Membership																								
Actual Group	No. of cases	1	2	3	4	5	6	7	8	9	10	12	15	16	17	18	19	20	21	22	23	26	30	32	33	40
1. Anntelope Wells	23	23/100%	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0
2. Cochetopa	20	00/0	20/100%	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0
3. Jemez	70	00/0	00/0	70/100%	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0
4. Grants Ridge	20	00/0	00/0	00/0	20/100%	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0
5. Polvadera	30	00/0	00/0	00/0	00/0	30/100%	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0
6. Red Hill	27	00/0	00/0	00/0	02/7.4%	03/11.1%	21/77.8%	00/0	01/3.7%	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0
7. Government Mt.	14	00/0	00/0	00/0	00/0	00/0	00/0	14/100%	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0
8. San Antonio Pk.	20	00/0	00/0	00/0	00/0	00/0	00/0	00/0	20/100%	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0
9. Cave Creek	17	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	17/100%	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0
10. Superior	31	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	23/100%	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0
12. Mule Creek	31	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	30/96.8%	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0
15. Superstition Mts.	03	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	03/100%	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0
16. Ash Fork	05	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	05/100%	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0
17. OLeary Peak	05	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	04/80%	00/0	01/20%	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0
18. Sitgreaves Peak	06	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	05/83.3%	00/0	00/0	05/83%	00/0	00/0	00/0	00/0	01/16.7%	00/0	00/0
19. Robinson Crater	05	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	04/80%	00/0	01/20%	00/0	00/0	00/0	00/0	00/0	00/0	00/0
20. Kendrick Peak	05	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	05/100%	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0
21. Fish Sawmill	05	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	01/20%	00/0	04/80%	00/0	00/0	00/0	00/0	00/0	00/0	00/0
22. Agassize Fremont	05	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	05/100%	00/0	00/0	00/0	00/0	00/0	00/0
23. Burro Creek	05	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	05/100%	00/0	00/0	00/0	00/0	00/0
26. School Mine	25	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	21/84%	00/0	00/0	04/16%	00/0
30. Topaz Mts.	05	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	05/100%	00/0	00/0	00/0
32. Modena	02	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	02/100%	00/0	00/0
33. Black Rock	07	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	07/100%	00/0
40. Crater Lake	15	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	00/0	15/100%
Chacoan Artifacts	666	00/0	06/0.9%	388/58.3%	17/2.6%	52/7.8%	143/21.5%	10/1.5%	04/0.6%	00/0	03/0.5%	09/1.4%	00/0	00/0	00/0											

Table 5. Obsidian sources by time.

Time Material	2 500s	3 600s	4 700-820	5 820-920	6 920-1020	7 1020-1120	8 1120-1220	12 1220-1320	Total
Jemez	1 1.1	5 22.7	8 40.0	1 14.3	40 46.5	19 65.5	148 88.6	7 77.8	229 53.4
Grants	4 4.		3 15.0	1 14.3	8 9.3	2 6.9			18 4.2
Polvadera	7 8.0	3 13.6	1 5.0	3 42.9	8 9.3	3 10.3	8 4.8		33 7.7
Red Hill	61 69.3	10 43.5	5 25.0	2 28.6	24 27.9	1 3.4	3 1.8	2 22.2	108 25.0
Mule Creek			1 5.0			1 3.4	2 1.2		4 0.9
San Francisco	3 3.4	2 9.1			2 2.3	2 6.9	4 2.4		13 3.0
Superior		1 4.5			2 2.3				3 0.7
Modena	11 12.5	2 9.1	1 5.0		1 1.2	1 3.4	1 0.6		17 4.0
Cochetopa	1 1.1		1 5.0						2 0.5
Unknown					1 1.2		1 0.6		2 0.4
Total	88	23	20	7	86	29	167	9	429

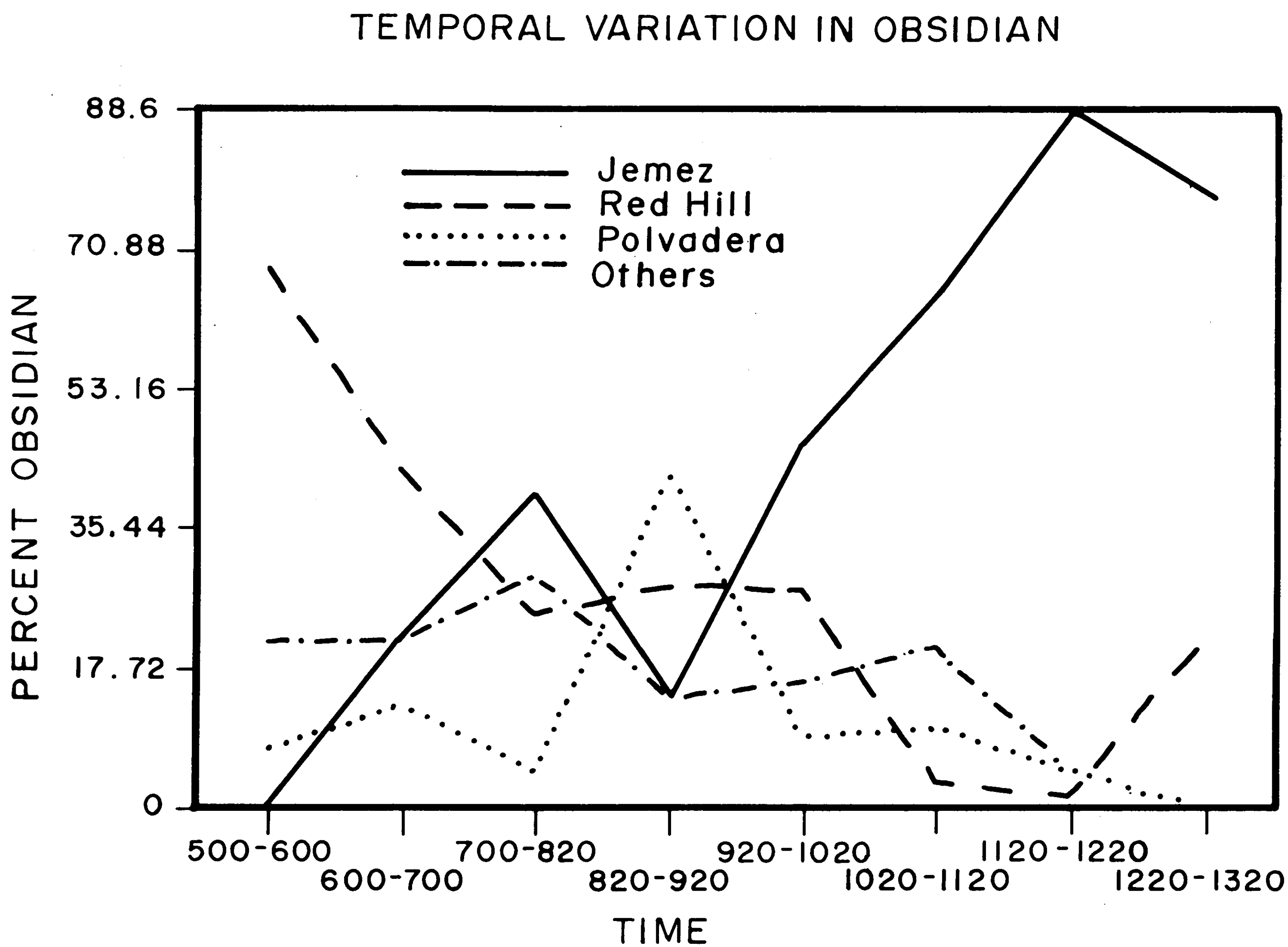


Figure 2. Temporal variation in obsidian.

temporal shift (about A.D. 700) in the direction of trade from Red Hill in the early time periods to Jemez in the later time periods. Trade in Jemez obsidian peaked during the period from A.D. 1120 to 1220. Polvadera Peak obsidian occurs in low frequencies through all time periods (the higher frequencies from A.D. 820-920 are a function of a very small sample size). Other sources are also rather evenly distributed throughout time, although they become less frequent in the later time periods.

General Trends In Material Use

Debitage vs Tools

The form in which obsidian arrived in Chaco also varies over time. The number of pieces of debitage per tool was calculated for early periods (pre-A.D. 920) and late periods (post-A.D. 920) for the three most frequent obsidian types. A high figure represents many flakes per tool, and a low figure, few flakes per tool:

	Jemez	Polvadera	Red Hill
Early (A.D. 500-920)	1.5	1.8	7.67
Late (A.D. 920-1320)	6.38	2.17	2.75

During the early periods Red Hill obsidian arrived as bulk material (raw material, cores, flakes), while during the late periods it was apparently introduced more frequently as finished tools. Exactly the opposite relationship is found with Jemez obsidian, where finished tools seem to have been imported during the early periods and bulk material during the late periods. The Polvadera Peak source shows little change in this relationship over time; the low ratio indicates that this material was generally procured as finished tools.

Cores

The presence of obsidian cores would be an indication that the manufacture of obsidian tools was taking place in the canyon. Ten obsidian cores were recovered, five from a single provenience at one site. The remaining five are from four different sources. Unfortunately, this small sample cannot be accurately used to support statements concerning temporal variability in obsidian manufacturing activities, but does indicate some on-site reduction of obsidian.

Summary

Contact to the south, where Red Hill obsidian is located, seems to have been strongest during the period before A.D. 700. This early period may also have seen evidence of contact with sources in Utah. After A.D. 700, emphasis in obsidian procurement shifts to the east (Jemez obsidian), and peaks between A.D. 1120 and 1220. Polvadera Peak obsidian use seems to have been steady, but its procurement may not have been direct as this material was probably acquired mostly as finished tools. The presence of other sources indicates that trade was widespread but not intensive with these distant areas.

Mechanisms Of Obsidian Procurement

Introduction

Of the 12 obsidian sources identified in the Chaco collections, distance to source ranges from 100 km to 570 km. With this wide range of sources and distances, acquisition methods undoubtedly differed from source to source and through time. Renfrew (1977) has modeled trade mechanisms for systems where the source was located greater than 200 km from the site. He describes distances of less than 200 km as being part of the "supply zone" with "a pattern arising largely from single journeys" (ibid., p. 84). While the sources of Chaco Canyon obsidian are mostly located at distances greater than 200 km, over 65% of the obsidian originates from those few sources that are within 200 km of the canyon, namely Jemez and Polvadera. The other common source, Red Hill, is located 200 km from Chaco. Direct procurement and regional exchange would thus seem likely for these three sources.

Another independent regional delimiter is the Chaco system, defined by the network of prehistoric roads and Chacoan sites (Figure 1). Only the Grants Ridge source falls within this region; however, the frequency of obsidian from this source in Chaco is very low. Of the other sources that fall outside the suggested system boundaries, only Jemez and Red Hill are found in relatively high frequencies. But material from these two sources occurs in much smaller quantities than do bulk imports such as ceramics and construction timbers, which were mainly procured from within the region defined in Figure 1. The record of obsidian movement within the region is different than that of ceramics and construction timbers, and it most likely was obtained through a less formalized trade system with other sites in the intervening regions.

Jemez Mountains

The Valles Caldera area is reported to have been sparsely occupied during Pueblo II and Pueblo III times (Winter 1981:181). Winter reports that the previous strategy of use of the Redondo Valley (on the slopes of the Valles Caldera) for acquisition of obsidian and production of bifaces exhibits an abrupt change about A.D. 1000. The area to the west of the Jemez Mountains, toward Chaco Canyon, is poorly known archaeologically, although recent work there by Mackey and Holbrook (1978) documents small sites with possible Chacoan affinities. They postulate that these sites may have been seasonally occupied and may have been sources of supply for the Chacoan area further west. Dick (1976) reports sites in the Llaves area (northwest of Jemez) dating between A.D. 1000 and 1300. The presence of sites in these areas and a possible increase in population during the period from A.D. 1100 to 1200 would certainly affect the nature of Chacoan access to Jemez obsidian.

Winter (1981) suggests that the quantities of Jemez obsidian found in Chaco Canyon, when coupled with the dearth of sites in the Jemez area during the Pueblo II and Pueblo III periods, indicates control by Chaco of the Jemez area. He suggests control on both local and regional levels, including restricted access to the source area and limited distribution of obsidian, mainly to administrative sites.

Winter's suggestion seems unlikely since (1) Jemez obsidian reaches its peak frequencies during the period from A.D. 1120-1220, which is after the Classic Bonito Phase developments and is a period of population decrease in the canyon, and (2) the postulated quantities of obsidian that were imported during this time period (A.D. 1120-1220) were probably small. At Pueblo Alto, extrapolating from the weight of excavated obsidian and the percentage of the site dug (during the period when obsidian was most common), a total of 3.6 kg of obsidian may have been imported to the site.

Of course, Alto is only 1 of 10 large Classic Bonito Phase sites in the canyon. If the quantity of obsidian at Alto is representative of average use at these other sites, the total would be about 50 kg over a 30-year period. This does not include, of course, the numerous smaller sites, but as 50 kg could be carried by one man in one trip, the quantity does not seem indicative of large-scale trade. Examination of surface collections from trash mounds at several of the Chaco town sites did not indicate that obsidian frequencies at these sites would exceed those at Alto (Windes and Cameron 1980-1981).

The above arguments indicate that the Jemez obsidian source was probably neither directly controlled by inhabitants of Chaco Canyon nor a major component of the extensive Chacoan regional system as defined by roads and outliers. The presence in Chaco of obsidian from the Jemez indicates trade between the two areas, but the nature of this trade must be further defined by archaeological work at the Jemez source and in the intervening regions.

Polvadera Peak

The source of Polvadera Peak obsidian is very close to the Jemez source; however, it occurs in low frequencies in Chaco collections and mostly as finished tools. Thus, it would seem that access to these two sources by Chaco inhabitants was different. The data on sites in the intervening regions between Jemez and Chaco also apply to the Polvadera Peak source. Just as there are no sites in the Redondo Peak area, Schaafsma (personal communication) notes no sites in the Piedra Lumbre Valley (near Polvadera Peak) for the time period A.D. 950-1150. Lack of extensive contact with this area seems the most likely explanation for the low frequencies of Polvadera Peak obsidian in Chaco Canyon.

Red Hill

Red Hill obsidian occurs most frequently in the early time periods at Chaco, pointing toward trade networks to the south of the canyon during Basketmaker III and the early Pueblo periods. The presence of ceramics from the Red Mesa Valley in Chaco during these early time periods (H. Wolcott Toll, personal communication) is another indication of southerly trade. The Red Hill area seems to have had a large population during this early time period (Danson 1957; Bullard 1962). Longacre (1964) notes a period of rapid population increase for adjacent areas of eastern Arizona after A.D. 700. This increase in population in the Upper Little Colorado area may be related to the shift in source of Chacoan obsidian from areas south of the canyon (Red Hill) to areas east of the canyon (Jemez). The continued presence of small amounts of Red Hill obsidian in late sites may be a result of sporadic trade with this area or may indicate the scavenging of material from early sites by the later inhabitants.

Other Sources

Long-distance trade (greater than 200 km) was known throughout the Southwest during the Pueblo period (Haury 1976; Hudson 1978) and involved exchange of minerals, shell, obsidian, and other items. A recent study by Mathien (1981) of long-distance trade to Chaco Canyon concluded that a down-the-line trade network was the most likely model for the exchange of distant exotic goods. The identification of obsidian from sources probably fit this same model, and their occurrence in Chaco Canyon sites cannot necessarily be used to indicate direct contact of the canyon inhabitants with these areas.

Conclusions

Trace element analysis has been used to correlate obsidian artifacts recovered from Chaco Canyon to 12 obsidian sources. The most significant result of this study is the evidence of a temporal shift in obsidian sources exploited. Prior to A.D. 700, Red Hill obsidian occurred most commonly, while after A.D. 700, obsidian from Jemez and Polvadera become more frequent, indicating a shift in the direction of trade. The reason for this shift may have been practical: Jemez obsidian is closer to Chaco Canyon than Red Hill obsidian and it occurs more abundantly and as larger nodules. Although the lack of extensive trace element analyses leave the results of this study open to question, Findlow and Bolognese (1982) have related shifts in patterns of obsidian exchange in the Southwest to changes in social systems.

The quantity of obsidian recovered from Chaco Canyon is relatively sparce. Out of 34,000 pieces of chipped stone recovered during almost 10 years of excavation, only 665 were obsidian and almost half of these were recovered from a few proveniences at Pueblo Alto. The number of chipping episodes represented by these flakes may be few. Nine of the obsidian source areas identified as represented in Chaco Canyon occur infrequently. Even the three sources that occur in higher frequencies do not necessarily indicate large-scale trade. Thus, it seems likely that obsidian was not a major part of the regional exchange system postulated for Chaco Canyon by Judge (1979) but was probably part of a less formalized mechanism of exchange.

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SOCIAL AND ECONOMIC IMPLICATIONS OF JEWELRY ITEMS OF THE CHACO ANASAZI

Frances Joan Mathien

Abstract

Analysis of ornaments and minerals recovered during recent National Park Service excavations in Chaco Culture National Historical Park provided sufficient data to identify jewelry workshop areas after A.D. 920 in several sites of the Chaco Anasazi. Whether these indicate the presence of full-time craft specialists is not certain; however, these data, when combined with those obtained by other researchers, suggest the presence of a ranked society among the Chaco Anasazi during the Bonito Phase (A.D. 920-1120).

Introduction

During the past decade several investigators have suggested that some form of ranked society may have existed in Chaco Canyon (Grebinger 1973; Judge 1976; Judge and others 1981; Schelberg 1979, 1982; Vivian 1970a, 1970b). Here an attempt will be made to utilize data on ornaments and minerals obtained during recent National Park Service (NPS) excavations, archival material and artifacts housed at the Division of Cultural Research, and the published literature in order to suggest one aspect of social organization of the Chaco Anasazi that may be useful when evaluating social complexity.

Methods

Over 6,000 mineral and shell items dating from the Archaic through Navajo occupations were recovered during recent NPS excavations. These were examined by the author as part of the Chaco Project analyses. Overall site summaries, prepared by site excavators, were used as a basis for estimating the temporal introduction of various material types into the system. More than two dozen organic and inorganic materials were utilized by the inhabitants of the area, including Archaic and Navajo, for nonutilitarian purposes. Twenty-four species of marine shell were identified by Helen DuShane, Research Associate, Division of Malacology, Los Angeles County Museum of Natural History; their source areas were determined from Keen's (1971) documentation of shells from the Pacific Coast. Mineral identification and source areas were determined with the assistance of David Love and A. Helene Warren (who provided type collections and advice) and by reference to Northrop (1959). Source areas were classified into three categories:

1. Local: Materials found naturally in and around Chaco Canyon.
2. Basin: Materials available within the San Juan Basin.
3. External: Materials not found within the San Juan Basin and imported from long distances.

Results

When the presence/absence and ranges of material types were calculated, several patterns were observed.

Archaic - Pueblo I

Material from three excavated Archaic-Basketmaker II sites (29SJ126, 1156, and 1157) in the canyon was used as a baseline against which to compare temporal appearances of other material types, as well as the use of ornaments. Results of the analyses suggest that Middle Archaic inhabitants did not use ornaments but did collect soft materials (e.g., limonite), possibly for making pigments. During the Late Archaic-Basketmaker II period the use of seed and bone beads is documented, and additional soft minerals were found. While argillite, gypsite, hematite and limonite are all locally available, the presence of malachite and a freshwater clam suggests utilization of material from within the larger area of the San Juan Basin.

There is a hiatus in time between excavated Archaic/Basketmaker II sites and excavated Basketmaker III sites in Chaco Canyon. With the adaptation to increasingly sedentary life during Basketmaker III, there is a definite increase in the number of material types recovered. *Olivella dama* and *Glycymeris gigantea* shells, as well as turquoise, suggest participation in exchange networks that linked Chacoan inhabitants to areas as distant as the Gulf of California. Azurite, garnet, steatite, shale, and sulphur suggest increased use of minerals found in and around the mountains peripheral to the San Juan Basin, particularly toward the west where steatite and high quality garnets could have been obtained. Several of these new materials were used as ornaments, or at least attempts to fashion them were observed. For example, a single garnet was recovered at 29SJ116. Several attempts at drilling were evident, all of which were unsuccessful. Garnet has a hardness of 6.5-7.5 on the Moh's scale; this may have been beyond the limits of Anasazi technology. Several other garnets have been recovered in Chaco (one in Room 330 at Pueblo Bonito [Judd 1964] and on site surfaces [W. Reiter, personal communication]); however, none of these were worked. This contrasts with the recovery of finished shale, calcite, and turquoise beads that have a hardness of 6 or less on the Moh's scale.

New material types found during excavation of Pueblo I sites include galena, iron, sepiolite, and serpentine--all available within the basin. One new shell species, *Haliotus cracherodii*, indicates long-distance trade networks extending to the coast of California.

Bonito Phase

Shell

A major change in quantity of ornaments and the introduction of different shell species occurs during the Bonito Phase (defined by Toll and others 1980). This correlates well with major architectural developments in the town sites. A total of 17 new genera of shell from the Pacific Coast and northern Mexico indicate continuation of long-distance exchange systems, but the number of items are too few to support any hypothesis regarding frequent or intense interaction among the inhabitants of these regions. Of the 21 species of shell that appeared during the Bonito Phase, 8 were found in proveniences clearly assigned to the Early Bonito Phase (A.D. 920-1020). These are:

1. Gastropods (snails): *Conus perplexus* Sowerby, 1857; *Episcynia medialis* Keen, 1971; *Oliva* sp.; and *Oliva incrassata* [Lightfoot, 1786].
2. Pelecypods (clams): *Argopectin circularis* Sowerby, 1935; *Chama echinata* Broderip, 1835; *Spondylus calcifer* Carpenter, 1857; and *Trachycardium* sp.

Other species may also have been introduced during this time period, but mixed proveniences do not allow finer separation. The *Nassarius* sp. shells from Kin Kletso date to the Late Bonito Phase (A.D. 1120-1220), which correlates well with information from the site of Bis sa'ani (a Chacoan outlier also dating to this time period) where *Nassarius* shell was also recovered (M. Marshall, personal communication). Judd (1954) reports *Nassarius* sp. shell from Pueblo Bonito, but the lack of detailed description of provenience precludes exact dating of the appearance.

Table 1 summarizes the distribution of 64 shells representing 17 genera and 21 species found during recent survey and excavation or among material from earlier excavations. *Olivella dama*, *Glycymeris gigantea*, and *Haliotus cracherodii* are excluded from this list as they appear during earlier occupations and represent 88.7% of the 529 marine shells recovered. While this sample is probably not statistically valid for sophisticated analytical purposes, it does suggest that access to these rare shell species was not limited to inhabitants of larger towns. The number of shells are approximately equally distributed between large and small sites. Nor are those found in the villages substandard in workmanship. Figure 1 illustrates nine shell pendants recovered from site 29SJ627, a village on the south side of Chaco Wash (Truell 1979). These are listed in Table 2. Similar well-made objects of argillite, jet, and turquoise have also been recovered from small sites.

Jewelry Workshops

Jewelry workshops have been identified at several sites within the canyon (Table 3). Determination was based on content and context since numerous scraps

Table 1. Bonito Phase--shell distribution.

Shell Type	Total No.	No. at Small Sites	No. at Large Sites
Cerithidea albondosa	2	1	1
Cerithium sp.	1	1	0
Conus perplexus	2	2	0
Episcynia medialis	2	1	1
Melangonia patula	3	3	0
Nassarius sp.	2	0	2
Oliva sp.	4	4	0
Oliva incrassata	7	6	1
Serpulorbis oryzata	1	1	0
Strombus galeatus	2	1	1
Turitella leucostoma	1	1	0
Argopectin circularis	2	1	1
Chama echinata	20	1	19
Choromytilus palliopunctatus	2	0	2
Glycymeris maculata	3	3	0
Laevicardium elatum	3	3	0
Lyropectin subnodosus	1	1	0
Spondylus calcifer	1	0	1
Spondylus princeps unicolor	3	1	2
Trachycardium sp.	1	1	0
Trachycardium sp., probably *T. panamense*	1	1	0
TOTAL	64	33	31

Table 2. Site 29SJ627--shell pendants

FS No.	Species	Provenience	Dating
1829	*Trachycardium* sp.	Pithouse C, fill	900-1000
2802	*Haliotus cracherodii*	Pithouse C, fill	900-1000
5956	*Glycymeris gigantea*	Kiva E, S. recess	920-1120
5077	*Glycymeris gigantea*	Pithouse C, fill	900-1000
666	*Argopectin circularis*	Test trench 5	Undated
2315	*Turitella leucostoma*	Grid HL-2	Undated
5735	*Cerithidea albondosa*	Kiva E, Layer 5	920-1120
1609	*Strombus galeatus*	Kiva D, fill	1000-1040
4772	*Haliotus cracherodii*	Kiva D, balk 1	1000-1040

Table 3. Bonito Phase--Possible jewelry workshops.

Time Period	Site Number	Provenience
920-1020	29SJ1360	Kiva B, Bench Plaza Area 5, Floor
	29SJ629	Pithouse 2, Floors 1 and 2 Plaza Grid 9, Floor and Pit area
	29SJ389	Plaza Grid 8, Pit
1020-1220	Bc 51	Room 34, second story
1105-1220	Pueblo del Arroyo	Rooms 24-26
1100-1250	Una Vida	Room 23, Floor
1120-1220	Kin Kletso	Room 5, ash lens/fill
	Kin Nahasbas	Kiva Bench and Floor
1000-1150	Bc 59	Room 9
920-1220	Pueblo Bonito	Probably several

and partially completed turquoise and shell ornaments are often recovered from kiva pilasters (Judd 1964), sealed pits, and other proveniences that suggest these materials served several functions. Some cases are better documented than others, but it is felt that workshop activity can be suggested for:

29SJ1360. Site 29SJ1360 is a village site located on a ridge extending north from Fajada Butte (McKenna 1981). Two separate workshop areas have been identified at this site. Both date to the Early Bonito Phase (A.D. 920-1020).

First, on the bench of Kiva B were 34 pieces of turquoise, as well as 8 of hematite, 2 of limonite, and 11 of selenite. The turquoise pieces included 1 complete pendant, 2 pendant blanks, 1 other partially worked piece, 17 modified pieces, 4 unmodified pieces, and 7 tiny pieces of debris. This small amount suggests one man probably worked in the kiva. Akins (1980) found four passive abraders on the floor and one active abrader on the bench that indicate a work area and support the conclusion reached from the analysis of ornaments and minerals alone.

Second, the floor of Plaza Area 5 was probably the locus of another workshop. There were 10 pieces of turquoise, 71 shale beads, an unmodified piece of selenite, and a feldspar crystal. The turquoise pieces included one bead blank, four modified, three unmodified, and two small pieces of debris. In the fill above the floor were 10 additional pieces of turquoise.

29SJ629. Site 29SJ629 is another small house site that was inhabited beginning in the Early Bonito Phase. It is located in Marcia's Rincon on the south side of Chaco Wash (Windes 1978). The village had a considerable amount of turquoise in various rooms, pithouses, and in the plaza. While Windes (1978) felt there were several work areas, only two have been well documented.

First, Pithouse 2 had two living floors. Floor 1 had 553 pieces of turquoise scattered in three pits (Nos. 1, 2, and 6) and along the wing wall. These consisted of 2 pendant blanks, 7 modified pieces, 2 unmodified pieces, and 542 pieces of debris. In addition, the excavators recovered hundreds to thousands of worked pieces of turquoise, including beads in various stages of completion (N. Akins, personal communication) that cannot be located for analysis. Two pieces of selenite and a passive lapidary abrader also were found in this area. Floor 2 had 11 pieces of turquoise in Baking Pit 1 and Other Pits 2, 5, and 10. Two were unmodified and the remainder were small and classified as debris. While no lapidary abraders were associated with the lower floor, three were found either on the upper floor or in the fill above it (Akins 1980). These two floors probably represent one family's living quarters that were refurbished through time.

Second, in the plaza outside of Room 7 is a floored area with two hearths and several pits. Approximately 262 pieces of turquoise were found on the floor. Again, partially completed or broken ornaments were mixed with modified and unmodified pieces and debris. In Pit 1, which was associated with the floor, 1163 pieces of turquoise were recovered. Included were 2 pendants, 1 pendant blank, 8 beads, 20 bead blanks, and 2 inlay. Many of the remaining pieces of debris were pinhead in size. Akins (1980) documents 31 passive lapidary abraders from this pit. No other minerals were found. This contrasts with the contents of Pit 14 located just to the south, which contained 292 pieces of selenite, 5 limonite, 2 lignite, a clay pendant, and 5 Glycymeris gigantea bracelet fragments in addition to 10 pieces of turquoise. Numerous grinding tools (but no lapidary abraders) and relatively high counts of corn pollen were also found in Pit 14. The proximity of these two pits and the contrast in their contents suggest that specialized work areas existed. Another pit, No. 6, contained 3 pieces of turquoise, 149 of selenite, 2 Olivella dama, 1 of hematite and 1 of jet.

As at 29SJ1360, these work areas dated to the Early Bonito Phase. The contrast in the amount of turquoise debris suggests greater intensity of labor at 29SJ629. Additional evidence to support this conclusion comes from Akins' (1980) study of abraders; 70.3% of the passive lapidary abraders recovered from all sites during recent excavations were found at 29SJ629. Lekson (personal communication) also found a number of smaller drills (17 small fortuitous perforators) at this site that may have been used as lapidary tools.

Pueblo Alto. Site 29SJ389 (Pueblo Alto) had some evidence of Early Bonito Phase work material in Plaza 1, Grid 8 (Windes 1977). A test trench through the plaza floor, through the fill beneath the floor, and into a pit, provided 23 pieces of turquoise (2 beads, 7 modified pieces, 5 unmodified, and 9 pieces of debris), 63 shale beads, 1 shale inlay, 10 pieces of selenite, 27 of limonite, 22 calcite beads, 5 Glycymeris bracelet fragments, 1 Chama echinata bead, 9 pieces of hematite, 9 of quartzite, and 34 of gypsite. One active lapidary abrader was found in the pit (Akins 1980). This is tentatively labeled as debris from a jewelry workshop. Windes (personal communication) thought this material may have been deposited as plaza fill and represented use by early occupants of the site.

Bc 51. Bc 51 is a village site located near Casa Rinconada in the rincon across from Pueblo Bonito. Originally excavated by the University of New Mexico field school during the 1930s (Brand and others 1937), it was stabilized by the National Park Service during the 1950s. Because the walls had been cleared but not numbered during the 1930s, Gordon Vivian assigned Room 34 to an area he described as an ornament workshop. Included in the remains of an upper story were 393 pieces of turquoise in various stages of manufacture, 328 of gilsonite, 224 of red shale, 90 tubular bone beads, 16 travertine cylinders, 2 hematite cylinders, a malachite nodule, a piece of red ochre, 3 Olivella shells, 2 miscellaneous shells, 3 flakes (possibly Haliotus), bird claws and bird beaks, 14 quartz crystals (9 complete ones with wear indicative of graving or abrading tools), chipped stone, knives, scrapers, points, axes, and a ground sandstone tablet that was well-shaped and small and suggested use in ornament manufacture (Vivian 1970a). This probably dates post-A.D. 1000.

Pueblo del Arroyo. Pueblo del Arroyo is a town site just west of Pueblo Bonito. In Room 9, beneath a considerable amount of debris on the floor in the northwest corner, were a handful of turquoise and shell chips that Judd (1959: 10) considered to be from a jeweler's workbench. This room was a long, narrow exterior room in the northwest corner of the site. Due to poor construction it was later subdivided by room walls and used as a trash dump. Originally several doorways led into an internal room complex that was linked by numerous connecting doorways. Among these (later separated into smaller segments by blocking up doorways) were Rooms 24 and 26 that remained accessible to one another through an intermediate room with open doorways. Judd (1959:125) remarks that while turquoise was sparse at this site, "we have 10 smaller shaped pieces of turquoise, mostly tesserae and a handful of chips from a lapidary's workbench in Room 24." He illustrates a flat sandstone abrader (Judd 1959:88, Fig. 30) and two sandstone files (Judd 1959:89, Fig. 31) from a total of six delicate abraders, all broken, that were found in Room 26. Thus, it is inferred that this northwest corner of the pueblo housed a craftsman whose debris and work tools date from A.D. 1120-1220.

Una Vida. Una Vida is a town site partially excavated in 1960 by Gordon Vivian as part of the Ruins Stabilization Program. During 1978, two members of the Chaco Center staff (Nancy J. Akins and William B. Gillespie) returned to several of the previously excavated rooms in order to clear floors and locate floor features. In Room 23 were a number of artifacts still on the floor. Among them were 14 pieces of turquoise (1 inlay, 8 debris, 3 modified, and 2 unmodified) along with 2 Haliotus shell inlays and 2 unmodified pieces of calcite. Cataloged artifacts from Vivian's excavations in this room included about 100 turquoise bits, a turquoise bead, and 9 Glycymeris bracelet/pendant pieces found while washing sherds from the fill. Based on recent excavations and these cataloged artifacts, it is suggested that an individual living in Room 23 may have worked turquoise. Based on ceramic associations this room is dated A.D. 1100-1250.

Kin Kletso. While Vivian and Mathews (1965) did not describe any work areas from the town of Kin Kletso, a review of the artifact catalogs and examination of turquoise in the Chaco Center collection revealed that there were 49 turquoise pieces in an ash fill/refuse lens in Room 5. Examination of the artifacts suggests workshop debris. The turquoise pieces include 17 disk beads, eight mosaic pieces, seven bead fragments, three pendant fragments, four modified, five unmodified, and five pieces of debris. In addition there were 246 shale disk beads, 1 red stone pendant, 1 purple/red stone disk bead, 14 broken slate beads, 41 Olivella beads, 2 Alectron shells, 2 nacreous shell fragments, 8 other shells, 2 argillite pieces, and 2 bone die. While this room cannot be identified as the workshop area, the material suggests a workshop did exist at the site, probably between A.D. 1120-1220.

Bc 59. While there are no formal reports on the 1947 excavations at Bc 59, a village near Casa Rinconada on the south side of Chaco Wash, a catalog card accompanying a McElmo bowl curated in the Maxwell Museum (47.11.32 or Bc 10/5) indicates its provenience as Room 9, beneath the outlines of a sealed doorway in the east wall. It was noted to have contained 108 pieces of turquoise and was associated with work implements of stone, antler (horn?), and bone. The turquoise was not located by the museum staff, but an examination of the Chaco Center collections revealed 235 pieces of turquoise (including 3 inlay and 4 bead blanks) from Bc 59. The catalog card (C-2026) listed these as previously uncataloged, provenience unknown.

Field notes for Room 9 describe a black and white pot found in the northeast corner 57 inches from the top of and near the east wall. The pot was complete and hollow, with the opening covered by a small masonry top on which were many (apparently unworked) pebbles of turquoise plus a piece of chalcopyrite in granitic matrix. Other notes concerning Room 9 are sketchy, and the discrepancy in the number of turquoise pieces cannot be resolved. Since there are more pieces of turquoise actually at the Chaco Center than listed as recovered with the bowl, it is assumed these pieces do represent the missing turquoise. Probable dates for this room are A.D. 1000-1150.

Pueblo Bonito. Pueblo Bonito is the largest town in Chaco Canyon and was the first site in the canyon to be excavated. Identification of workshop areas at this site are tentative. In his report, Pepper (1920) does note several types of workshops: Room 2--arrowpoints; Room 18--wooden objects; Room 40--possibly jewelry; and Room 70--metates. There was also a considerable amount of shell for making ornaments in the debris of Rooms 36 and 37. Judd (1954) does not identify any workshop areas for jewelry making, but he did recover one sandstone abrader in Room 328 that could have been used for that purpose.

Review of catalog cards from the American Museum of Natural History revealed:

1. Turquoise fragments and worked pieces were found among the posts in the southeast corner of Room 33. There were also rough pieces found in several corners and general debris. These occur along with over 56,000 other pieces in the burial room and were probably intentionally placed there. While it is not a workshop area, the debris suggests workshop material that may have come from this site.
2. Room 38 contained sand with turquoise. Other ornaments in the room included finished pendants, beads, inlaid jet objects, and shell as well as other minerals and ground stone tools, ceremonial sticks and macaws. It may have been a storeroom for materials or possibly a workshop area.
3. Rooms 78, 85, 86, 102, 105, 106, 107, 110, 156A, 163 and 170 all had debris, pieces of turquoise in matrix and other turquoise pieces. These suggest a workshop (or possibly several workshops) somewhere in this site.

While it is impossible to pinpoint a jewelry workshop area, it does seem likely that there had been some type of jewelry making based on the number of rooms that had fragments, the number of scraps that appeared in pilaster offerings in several kivas, and the recovery of a sandstone abrader. The dating of proveniences for these items ranges from Early through Late Bonito Phase and more than one generation may have been involved in manufacture.

Kin Nahasbas. Kin Nahasbas is a great kiva located on a bench on the north side of the canyon above Una Vida. It was excavated in 1935 by the University of New Mexico/School of American Research field school by Dorothy Luhrs (1935) and reported in Vivian and Reiter (1965). The masonry suggested two construction periods: the first ranged from A.D. 945-1030 or 1030-1070 or possibly even later while the second was placed at A.D. 1100 or later (Vivian and Reiter 1965).

Review of the catalog cards prepared by Luhrs revealed there were a number of ornaments found on the bench of the kiva (Table 4). These included one modified piece of slate, one turquoise fragment,

Table 4. Jewelry items from Kin Nahasbas.

Provenience	Catalog No.	Material Type	Artifact Type
Level 2	KN 1935.4	1 Bone	1 Bead
Level 4 NE	KN 1935.8	1 Sandstone	1 Sphere
4	KN 1935.9	1 Bone	1 Bead
4 SW	KN 1935.18	1 Slate	1 Modified
4 NE, top of bench	KN 1935.10	1 Slate	1 Modified, perf.
	KN 1935.12	1 Turquoise	1 Fragment
	KN 1935.13	4 Black stone	4 Beads
Level 5, fill above fl.	KN 1935.21	13 White stone	13 Beads
5 NW	KN 1935.30	1 Black stone	1 Bead
5 floor and fill above	KN 1935.31	1 White stone	1 Bead
		3 Turquoise	3 Bits
5 fill	KN 1935.47	2 White stone	2 Beads
5 bench	KN 1935.46	3 Turquoise	3 Beads
		3 White stone	3 Beads
5 bench	KN 1935.48	1 Olivella	1 Bead
5 bench	KN 1935.49	? Turquoise	? Bits
5 bench	KN 1935.40	1 Clay	1 Ring
5 floor SE	KN 1935.54	3 Turquoise	3 Pieces
Level 6	KN 1935.55	1 Bone	1 Bead
6 Ab. SS fl.	KN 1935.57	1 Pink/white pc.	1 Bead
6 N of fire vault	KN 1935.61	1 Turquoise	1 Bead

three turquoise beads, an unknown quantity of turquoise bits, four black stone beads, three white stone beads, one Olivella bead, and one clay ring.

> Most of the beads, black and white, found in Kin Nahasbas were found on top of the bench. They would be imbedded in the plaster or lying directly on top of it. In one case there were four to five black beads found close together; in no one time was there a complete set or stringed set of beads found (Luhrs 1935:32).

Neither Luhrs' nor Vivian and Reiter's reports listed abraders or other tools associated with jewelry making. However, the catalog cards include one flat stone (KN 1935.51) found in Level 5. It is described as a "more or less rectangular piece of limestone with both sides flattened by use--two edges are apparent of this--both being somewhat rounded and slightly squared in places. By texture of the stone--the grinding was of a fine nature." Other small grinding stones were listed, but only this one was an abrading stone used in jewelry making (N. Akins, personal communication).

Discussion

Within Chaco Canyon evidence reveals some exotic materials (traded from areas outside of the San Juan Basin, particularly shell and turquoise) appear as soon as sedentary occupation occurs. However, the quantity of these materials and ornaments, in general, does not increase until the Early Bonito Phase. Access to well-made products is not limited to inhabitants of early towns. In addition to shell items (Figure 1), an exquisite jet ring was found in the fill of Kiva A at 29SJ1360, a village site. Its context dates A.D. 920-1020. Several argillite pieces from 29SJ627 (from the Bonito Phase) are carved into zoomorphic figures as well as pendants and beads. Even Late Bonito Phase inhabitants at 29SJ633 had finely carved lignite birds and disks.

Based on the variety of materials and artifact classes found in various Chaco sites through time, it is concluded that superior craft skills were developed among the Chaco Anasazi. Data from Basketmaker II sites in northeastern Arizona (Guernsey and Kidder 1921; Kidder and Guernsey 1919) reveal that finely made black beads were common by A.D. 400. Therefore, it is not surprising that the Chacoans were skilled craftsmen.

Data from the various workshop areas lead to the following inferences:

1. Turquoise or jewelry craft specialists were active in Chaco during the entire Bonito Phase. The earliest workshops date A.D. 920-1020, but others are found in A.D. 1120-1220 contexts.
2. Craft work was not limited to use of turquoise alone (e.g., Kiva B at 29SJ1360); it included a variety of materials (e.g., Bc 51).
3. Jewelry makers worked in both smaller villages and town sites, both during early and later time phases.
4. Recovered material suggests work areas were used by single workers, probably on a part-time basis. (There is no ethnographic or historic data presently available concerning the quantity of debris created by one jewelry worker over a specific period of time.) One possible exception to this is at 29SJ629, where the large numbers of abraders and small drills suggest that manufacture was more intensive. Windes (personal communication) feels this work took place within a short period of time (e.g., one year) based on the fact that very little other material was recovered from Pit 1. While some residential groups began to specialize in the manufacture of turquoise and other jewelry, the extent of this specialization (part-time vs. full-time) cannot be determined at present.

Data from the entire Chaco system in the San Juan Basin is limited. In addition to the workshops in Chaco Canyon, numerous pieces of turquoise from the surface of the Andrews site (private collection examined by author in 1979) suggest this material was also worked in other areas of the basin, particularly the south. There may have been some manufacture of turquoise at Aztec Ruin as there were bits of turquoise in the refuse of Rooms 47, 54, 65, 109, 110, 111, 112 (Morris 1928).

Swift (1980) reports a claystone bead manufacturing area at Shumway Pueblo, an Early Pueblo III village. Colors of material ranged from pinkish orange to pinkish red. Vivian's description of Room 34 at Bc 51 suggests several materials in addition to turquoise were manufactured in Chaco. Because of the

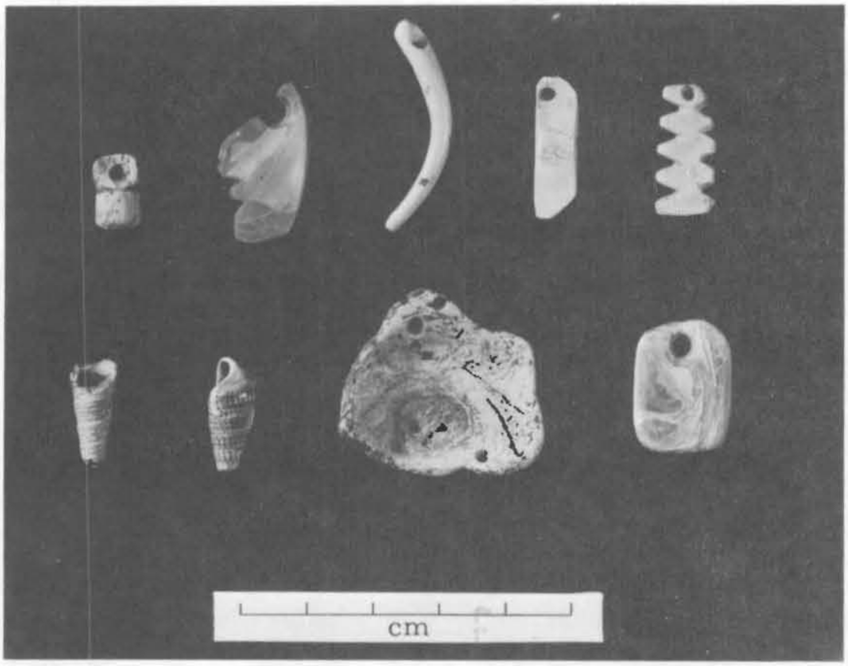

Figure 1. Nine shell items from 29SJ627.

limited amount of evidence regarding jewelry production, this proposition should be reevaluated at a later date.

Conclusions

Chacoan society maintained and increased its participation in long-distance trade networks for luxury materials that were established by Basketmaker III. The techniques for manufacture of fine beads were developed by the Anasazi of northeastern Arizona by Basketmaker II; dissemination of this information may have taken some time to spread to Chaco. This distribution could be an artifact of the currently excavated sites in Chaco Canyon and elsewhere as there are individual ornaments from Basketmaker III sites in Chaco. The earliest known workshops in the canyon are dated to the Bonito Phase, beginning about A.D. 920, but there is no definitive evidence that these were subsidized full-time craftsmen. The presence of craft workshops may indicate that the Chaco system represents an incipient ranked society, as the presence of craft specialists is one characteristic of chiefdoms enumerated by Service (1962). The evidence obtained from this study, when combined with that obtained by Akins and Schelberg (this volume) on burials, Lekson and others (1982) on architecture, and Powers (this volume) on the extent of the regional system, tends to support the proposal of a ranked society in Chaco that was suggested by Grebinger (1973), Judge (1976), Judge and others (1981), Schelberg (1979, 1982), and Vivian (1970a, 1970b).

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HYDRAULIC ENGINEERING ANALYSIS OF PREHISTORIC WATER-CONTROLLED SYSTEMS AT CHACO CANYON

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Abstract

Although prehistoric water-control features have long been subject to archaeological investigation, they have rarely been critically examined in terms of the hydrologic and hydraulic parameters of operation. Here, watershed computer modeling and channel routing techniques are applied to two water-control systems at Chaco Canyon to evaluate the performance and stability of these systems under assumed hydrologic conditions. Application of this modeling approach allows a more detailed assessment of the function, operation, and maintenance requirements of these systems than has previously been possible.

Introduction

Prehistoric water-control features have been recognized in the Chaco Canyon area for over a century and have been described and discussed by several authors (Hewett 1905; Vivian and Mathews 1965; Vivian 1972, 1974; Loose and Lyons 1976). The most detailed investigations have been by Gwinn Vivian (n.d., 1972, 1974), who located over 100 structures related to water control and conducted test excavations of many of them. On the basis of his investigation, Vivian (1972, 1974) has concluded that most of these features are parts of a standardized arrangement aimed at utilizing runoff from small watersheds along the canyon margins for agricultural production in the canyon bottom. This basic system, which Vivian suggests was repeated regularly through the canyon, involves diversion or capture of small watershed runoff and transportation through small canals or ditches to relatively complex and well-made masonry headgate structures, which are thought to have regulated water flow to adjacent field areas.

In his 1974 paper, Vivian describes one such system near Penasco Blanco (Figure 1) in some detail and discusses how its operation would be directly dependent on major summer rainful events and resulting runoff. Vivian offers some speculative figures for such runoff capacities but defers more detailed calculations, concluding that "runoff studies could provide invaluable information for Southwestern archaeologists" (Vivian 1974:105).

While most water-control structures in Chaco Canyon served agricultural functions, there are some that probably had other uses. Notable among these is a massive masonry dam that evidently impounded water in an alcove near the top of South Mesa on a small tributary of Weritos Rincon (Figure 2). Although Vivian and Mathews (1965) suggest this was an agricultural feature, its proximity to the mesa top pueblo of Tsin Kletzin, 750 m to the southwest, suggests that its primary use may have been as a domestic water source for the occupants of that site. Here, as with the Penasco Blanco diversion system, the water is derived from local runoff that usually occurs only with high intensity summer thunderstorms.

The intent of this paper is to offer a better understanding of how these structures may have functioned by providing more detailed estimates of what runoff amounts could be expected in each case. To do so, this study applies hydrologic and hydraulic engineering techniques to the analysis of the hydraulic characteristics of the Penasco Blanco canal and headgate system, and the Weritos Rincon Dam. Watershed computer modeling and channel routing techniques are applied to these two water control systems to evaluate their performance and stability. The study was performed for present hydrologic conditions that are assumed to be similar to those that existed during the Anasazi occupation of Chaco Canyon. By using a physical process computer model composed of watershed and channel routing components, a realistic representation of hydrologic processes can be achieved. The physical

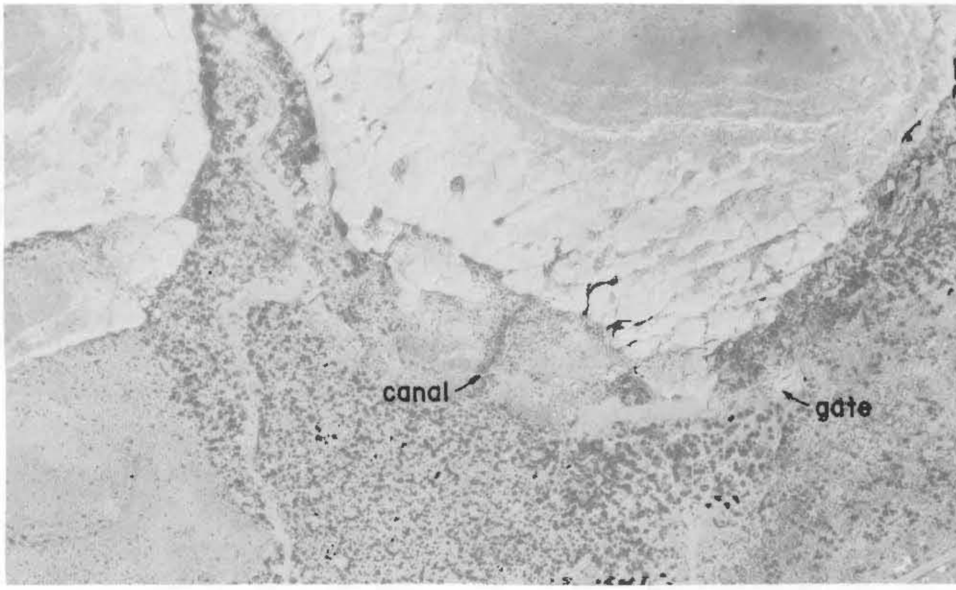


Figure 1. Aerial photograph (1971) of Penasco Blanco water-control complex. Major drainage at left is Vivian's (1974) "Rincon 4 North." North is to left. Scale is about 1:300.

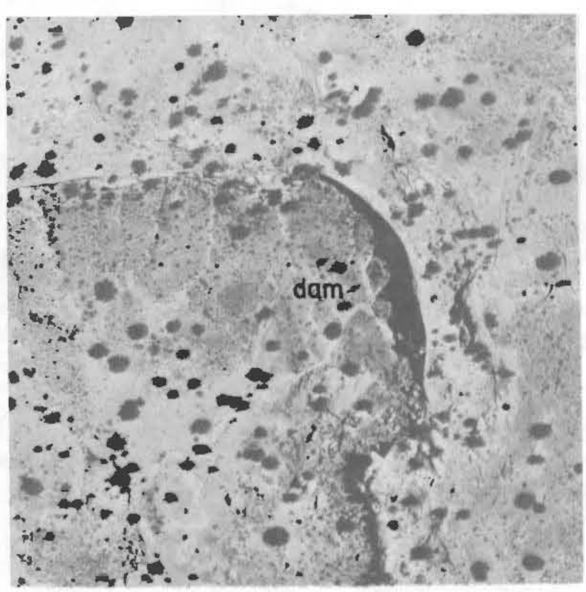


Figure 2. Aerial photograph (1971) of Weritos dam location. Modeled watershed is in upper right and extends beyond limits of the photograph. North is to bottom of photo. Scale is 1:3000.

process model permits investigation of both spatial and temporal changes in parameters that control the processes. This permits simulation of variations in, and response of part or all of, the systems by altering key parameters and assessing resulting response. Application of this approach allows assessment of the capacity and stability of prehistoric water-control systems in relation to watershed hydrologic output under assumed climatic and hydrologic conditions. In addition, this approach provides information relevant to archaeological questions regarding maintenance requirements, technological skills, and organization of labor.

This paper focuses on the presentation of this hydrologic and hydraulic model and the illustration of its applicability to archaeological problems. Only in the past ten years have there been many attempts to apply the concepts and methods of hydrology to better understand how prehistoric Southwestern water-control systems functioned. Most of these applications have been to Hohokam irrigation canals that utilized water from the large rivers of southern Arizona (Haury 1976). But in Chaco Canyon and in much of the northern Southwest, water control was on a much smaller scale and directed at utilizing local runoff events. Accordingly, a different set of modeling techniques are required to understand the hydrologic and hydraulic characteristics of these features. This study can be considered a trial or preliminary application of such techniques. It is by no means an in-depth study but instead is intended to make known the existence of such methods and their potential for better understanding prehistoric water control.

Assumptions And Model Description

The runoff simulation model used here was developed as a general purpose tool for examining runoff phenomena. It is basically an event model; that is, a model for examining the runoff resulting from a particular rainfall event. Models of this type are particularly useful for predicting runoff in ungaged ephemeral drainages such as those above the walls of Chaco Canyon. The model is a mechanistic formulation guided by assumptions simplifying the physical processes of rainfall runoff and sediment yield.

Assumptions governing model formation can be grouped into those affecting rainfall, interception, infiltration, overland and channel flow, and sediment transport. Summer runoff in these watersheds often results from short duration high intensity rainfall. Since this study is directed at examining the capacity of presumed Anasazi water control structures, it is assumed that these summer thunderstorms are the events of interest. Further, due to the size of the watersheds modeled, it is assumed that the storms were spatially uniform events with intensity varying through time.

The modeled storms used in this study are based on recent National Weather Service precipitation data from Chaco Canyon. Paleoclimatic data indicate that climatic conditions during Anasazi occupation were comparable to the present, but that summer precipitation was probably somewhat greater from about A.D. 950-1150 (Euler and others 1979). Since use of the Chaco water-control features is thought to have occurred in the latter part of this interval, the modeled storms may be conservative.

Using recent rain gage data taken at Chaco Culture National Historical Park, a frequency analysis may be performed to determine the size of the average annual storm and other storms of interest. Frequency analysis yields a total volume of rainfall corresponding to a given return period. The temporal distribution of that rainful must be determined or assumed. Obviously, if a storm of interest had a total precipitation volume of 5 cm, it makes a considerable difference in runoff characteristics whether that 5 cm occurs in five minutes or over one hour. Summer storms at Chaco are usually small, intense thunderstorms that move across a watershed relatively quickly (Simons, Li & Associates 1982). These storms vary temporally as well as spatially.

A number of methods are used to represent the temporal character of a rainstorm. The most common is the hyetograph, which is a plot of rainfall intensity versus time. The intensities are obtained by multiplying the rainfall volume by a set of nondimensional intensities, that is, a weighting function. Two commonly used methods are presented by the U.S. Soil Conservation Service (1972) and by the U.S. Bureau of Reclamation (1977) for deriving the weighting function. For this study, the SCS method was used for deriving the weighting function for a representative (or design) storm.

In modern hydraulic design based on hydrologic analysis, the design storm is usually an infrequent, very large event. The selection of this design event is a compromise between the desire to have the structure withstand all flows and the economics of building such a structure. In the case of the Anasazi structures, it seems probable that they were sized by experience (trial and error) rather than by design. This study assumes that the structures investigated were sized to be sufficiently large to handle most smaller events, but that they would probably be washed out and rebuilt after less frequent, larger events.

It is important to realize that rainfall frequency analysis is an analysis of extreme events. That is, one always asks the question, "What is the largest event that will occur on the average, once a year, once every ten years, or once every 100 years, and so on?" Since this study is limited to small events, the storms selected were the mean annual storm volume and a smaller storm volume. The mean annual storm derived from a Gumbel, or extreme value distribution, has a return period of 2 1/3 years. The other storm selected for this study has a return period of approximately one year. The storm volumes (volume per unit area) corresponding to these return periods were 1.91 and 0.84 cm, respectively. These volumes are derived by graphically fitting a Gumbel distribution to local rain gauge data. The basic premise here is that these small events are representative of a range of events commonly occurring during the summer or irrigation season. The larger storm is assumed to have occurred over a period of 60 minutes; the smaller is assumed to have occurred during 20 minutes. The storm hyetographs in Table 1 result when these volumes are distributed over time.

A portion of the rainfall is intercepted by foliage canopy, ground cover, and even rocks lying on the ground surface. Part of this water eventually reaches the ground by dripping from intercepting surfaces; however, the water that is held on these surfaces never reaches the soil and is for the most part lost to evaporation. In conditions of light rainfall or in dense forests this process cannot be ignored. In this case, the process is assumed to have a minor effect due to the sparcity of vegetation and ground cover and the high intensity of rainfall.

In most watersheds, infiltration, the process by which water enters the soil, plays the most important role in determining runoff characteristics. This model assumes that the infiltration process can be considered separately from the overland and channel flow processes. In reality, infiltration and runoff take place simultaneously once ponding occurs. Separating (uncoupling) these processes implies that the depth of water flowing on the surface does not affect the infiltration rate. Actually, the depth of ponded water, or of water flowing on the surface, adds its weight to capillary and gravitational forces on the water already in the soil pores. However, in the watersheds examined for this study, the gravitational force due to the depth of flow can be shown to be small compared to capillary forces in the soil, thereby justifying the uncoupling assumption (Eggert 1976). Infiltration calculations are performed to determine the volume of water lost from rainfall as a function of time. The difference between rainfall and infiltration rates is called the rainfall excess. It is this excess that is routed as overland and channel flow.

Further assumptions governing the infiltration process are as follows:

1. The soil is assumed to be a physically homogeneous, rigid porous media.

2. The infiltration process may be regarded as one-dimensional, i.e., vertical.

3. Initial moisture content is uniform throughout the soil.

4. The effect of the displacement of air from the soil has negligible influence on the infiltration.

5. Movement of water into the soil may be regarded as a continuous saturated wetting front entering an unsaturated soil.

6. Soil compaction due to raindrop impact is neglected.

Using the above assumptions and Darcy's Law, the average velocity of water above the wetting front in the soil may be determined. That is,

$$v = -K \frac{dh}{dz} \quad (1)$$

where v is the average velocity of the flow, K is a constant of proportionality usually called the hydraulic conductivity, z is the vertical dimension, and h is the piezometric head.

Piezometric head is a computational convenience used by hydraulic engineers to represent, in this case, the algebraic sum of the gravitational and capillary suction forces. That is,

$$h = -\eta - \psi \quad (2)$$

where η is the gravitational head, and ψ is the capillary suction head.

The assumption of a continuous saturated front states that this water enters the soil uniformly, saturating the pores above a distinct advancing water surface. The capillary forces are assumed to result from the averaged effect of surface tension in the pores. In general, these forces vary with soil type and structure. Since the soil is assumed homogenous, capillary effects are represented by a single averaged parameter. These assumptions may be used to derive a time explicit formulation of the Green-Ampt equation for infiltration (Eggert and others 1979). Further discussion of this method is beyond the scope of this paper. For additional information on the infiltration process, the reader is referred to Bouwer (1969); Green and Ampt (1911); Morel-Seytoux and Khanji (1974).

Numerous assumptions govern the representation of water runoff from the Chaco Canyon catchments. First, runoff from infiltrated water is neglected since, in these watersheds, the surface or excess rainfall response produces by far the largest discharges. Other assumptions affecting runoff hydraulics are as follows:

1. Flow may be represented as one-dimensional unsteady flow.

2. Manning's resistance equation may be used for resistance to flow.

3. Kinematic wave routing may be applied to both overland and channel flows.

4. The watershed may be transformed into a system of planes and connecting channel units. This process is illustrated simplistically for a two-plane case in Figure 3.

Assumptions 1 and 2 are commonly used in hydrologic and hydraulic analysis. The mechanics of flow require simultaneous solution of the partial differential equations of conservation of mass (or continuity), and conservation of momentum. These equations are in general very difficult to solve, but assumptions 1 through 3 greatly simplify them. The resulting equations of conservation for mass and momentum reduce respectively to:

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q_\ell(t) \quad (3)$$

where Q is the discharge (or volume rate of water flow), x is the downstream dimension, A is the cross-sectional area of flow, t is time, and $q_\ell(t)$ is the time varying lateral inflow per unit channel length. Under the kinematic wave assumption, the momentum equation becomes:

$$S_f = S_o \quad (4)$$

where S_f is the slope of the energy grade line and S_o is the average slope of the channel bed or land surface. Assumption 2 allows S_f to be expressed in terms of flow and channel characteristics. Manning's equation has the form, in SI units, of:

$$Q = \frac{1}{n} R^{2/3} A S_f^{1/2} \quad (5)$$

where n is an empirically defined "resistance parameter" and R is the hydraulic radius given by:

$$R = \frac{A}{P} \quad (6)$$

where P is the wetted perimeter of flow.

Equation 4 allows substitution of S_o, which is measurable in the field, for S_f in Equation 5. Routing the flow then becomes a problem of solving Equation 3 using Equation 5 to relate discharge and flow area. The routing equations described above are used for channel flow. The overland flow equations are identical in form to Equations 3 and 5 except that the channel is assumed to be very wide, allowing discharge per unit width, q , to be substituted for total discharge, Q ; depth of flow, y, to be substituted for the hydraulic radius, R ; and rainfall excess e(t) , to be substituted for discharge per unit length, q (t). In addition, A , becomes the area of flow per unit width, which is also the depth. Therefore, the equations for overland flow are:

$$\frac{\partial q}{\partial x} + \frac{\partial y}{\partial t} = e(t) \qquad (7)$$

and

$$q = \frac{1}{n} y^{5/3} S_o^{1/2} \qquad (8)$$

The solution approach for Equations 3 and 5, and Equations 7 and 8 is identical. Both sets of flow equations may be solved numerically and, under some conditions, analytically. The computer model applied in this study used both solution techniques for channel flow and only analytical techniques for overland flow. Again, details of the solution of these equations are outside the scope of this discussion. A number of excellent texts discuss the general theory behind flood routing (Henderson 1966; Chow 1959; and Eagleson 1970). Discussions of the details of the solutions used in this model appear in Li and others (1979); and Simons and others (1975, 1977a). A similar approach has been applied to the problem of present day erosion control at Chaco Culture National Historical Park and is described in Simons, Li & Associates (1982).

In addition to water runoff, this approach also models sediment runoff from watersheds. Physically based modeling of sediment yields is a complex process that first requires correct simulation of the hydraulics of runoff. The sediment portions of the model use the hydraulics described above to transport sediments. Sediment computations were made at both the Penasco Blanco and Weritos sites. However, much of the Penasco Blanco drainage is slick rock that yields virtually no sediment. Therefore, the sediment portion of the model has much greater significance at the Weritos site, and further discussion of sediment routing is presented in the Weritos section.

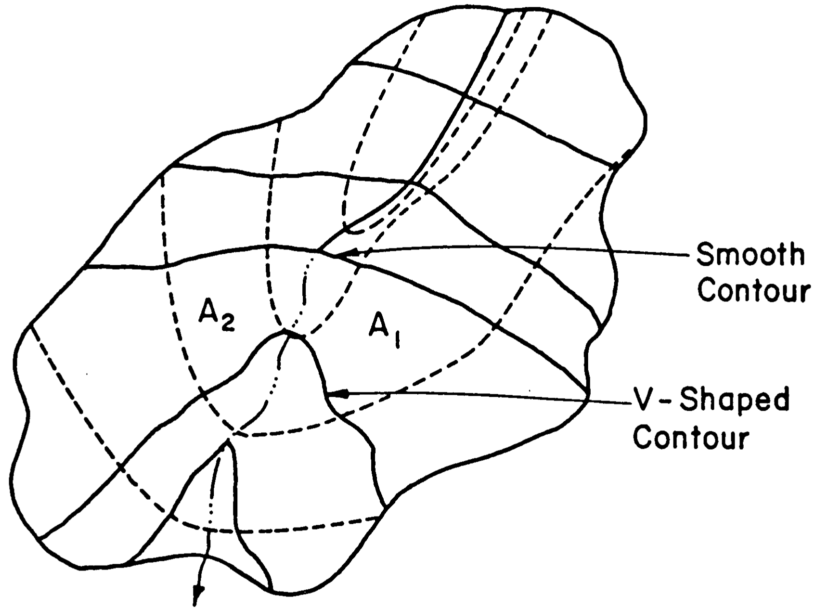
The inherent advantage of this approach is that hydrographs can be developed for storms of interest with a minimum of historical data and for a variety of assumed conditions. Modeling is based on the physical characteristics of the drainage basin and the nature of the rainstorm input. The best calibration procedure is to use rainfall-runoff data from the modeled watershed, but calibration may be accomplished by using data from a similar watershed. If, as in this case, these data are not available, this approach still provides a reasonable estimate of runoff since the model parameters are field measurable characteristics of the watershed. Further, since current hydrology is assumed to be applicable to the Anasazi period, current regional rainfall-runoff relationships may be used to guide model prediction and cross check for reasonableness of results.

Applications To Anasazi Water-Control Features

Penasco Blanco Complex

This complex of water-control features is located near the western end of Chaco Canyon across from the large pueblo of Penasco Blanco. It represents one of the better examples of the small-scale agricultural systems as defined by Gwinn Vivian (1972, 1974) and is the example described in his 1974 paper. Archaeological tests have been made by Gordon Vivian in 1964, Gwinn Vivian in 1971, and Gillespie in 1979.

Together these investigations have revealed a complicated array of features that show repeated use of the system over a period of time. Basic components include a ditch flowing from north to south along the base of the lower canyon wall, a set of masonry headgates that are thought to regulate water flow to field areas, and one or more shallow ponds or reservoirs adjacent to the gates (Figure 4). The upstream limit of the ditch is apparently defined by the large drainage denoted "B" in Figure 4. Exact articulation of these features and their arrangement at any single time is obscured by modifications and sequential replacement of components over time. For example, the gate complex consists of three adjacent headgate structures that elsewhere in the canyon are found singly (Figure 5). As illustrated by Vivian (1972), each of these structures involve a standardized construction centered on an approximately 2-m-long rectangular channel about 30 cm wide with a flagstone-paved floor and masonry walls. Vertical slabs set on either side and at the thresholds of both ends of the channel may have supported moveable covers. Figures 6 and 7 show two views of the headgate structure during excavation. In most cases, masonry walls perpendicular to the channel extend a short



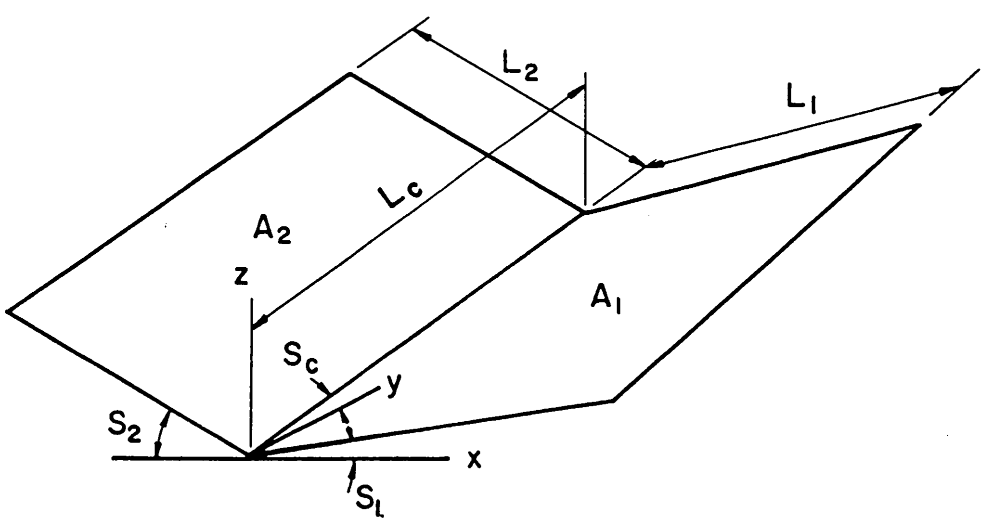


Figure 3. Geometric representation of 2-plane subwatershed (after Wooding 1965). Upper, original watershed topographic map; Lower, Wooding plane representation.

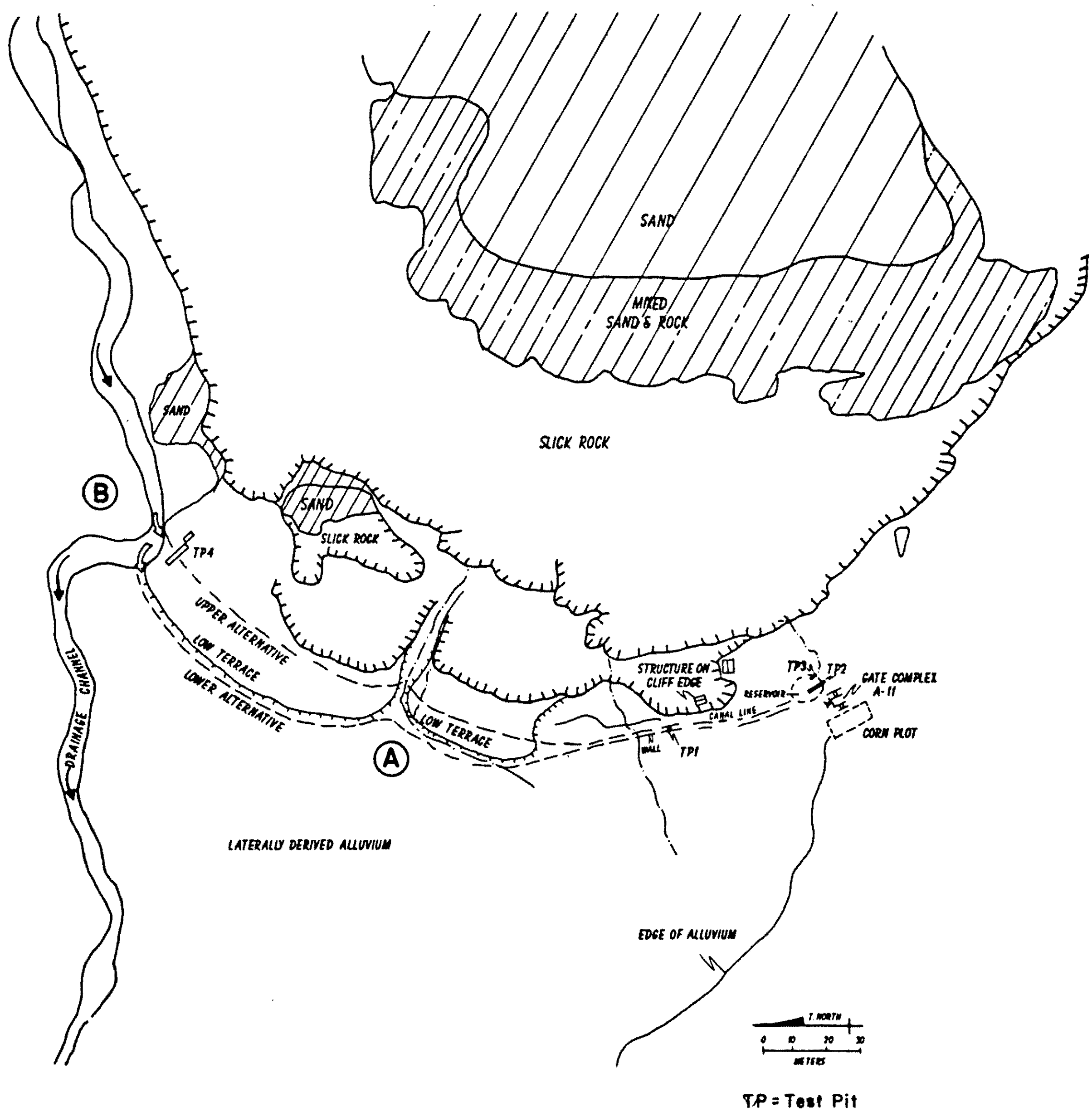


Figure 4. Plan view of Peñasco Blanco water-control system; TP = test pit.

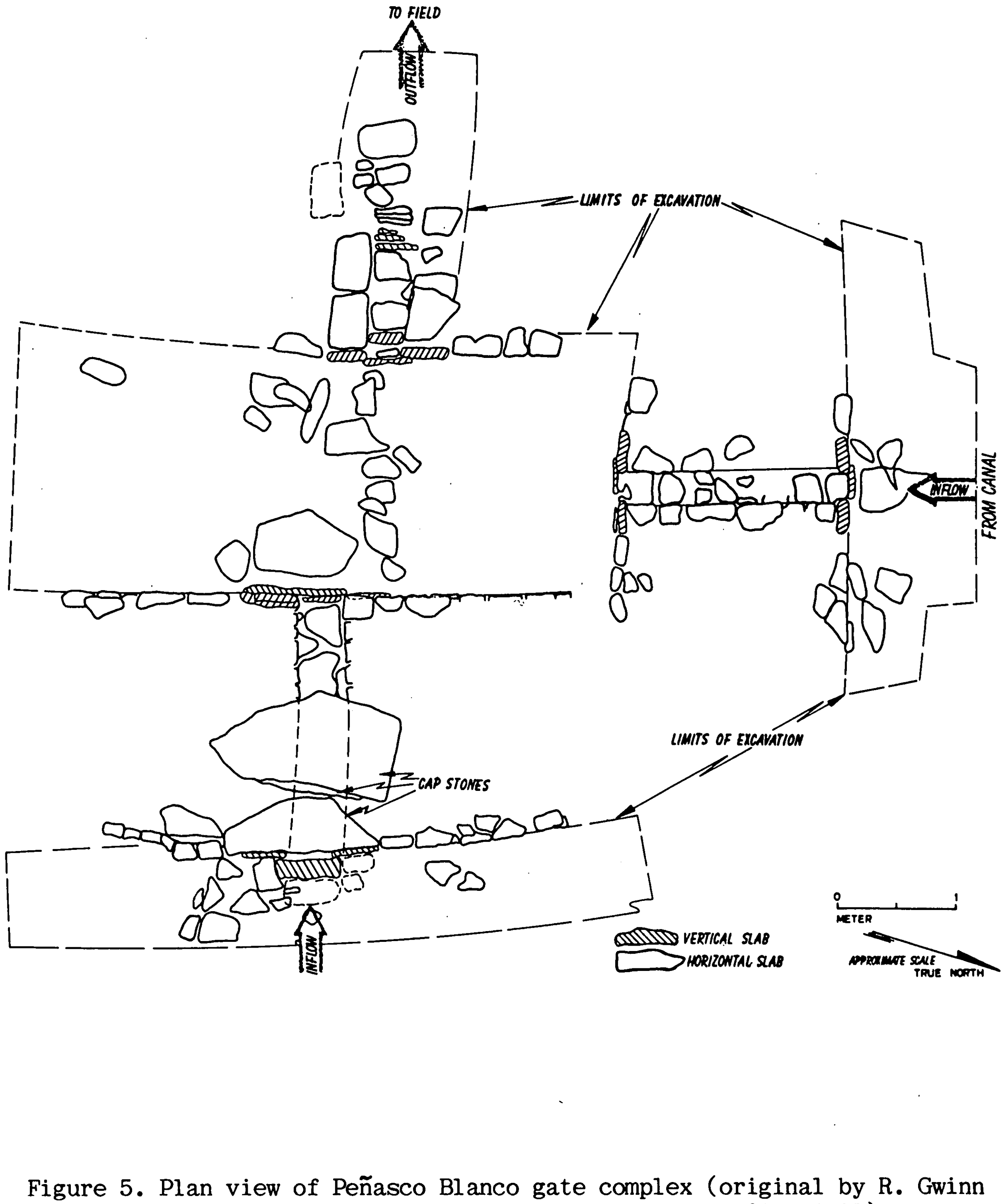


Figure 5. Plan view of Peñasco Blanco gate complex (original by R. Gwinn Vivian, Chaco Canyon Water-Control Project, Site A-11).

Figure 6. East gate of Peñasco Blanco gate complex from the west. Note upright slabs framing the channel opening, masonry walls to either side, and capstones in background (courtesy R. Gwinn Vivian).

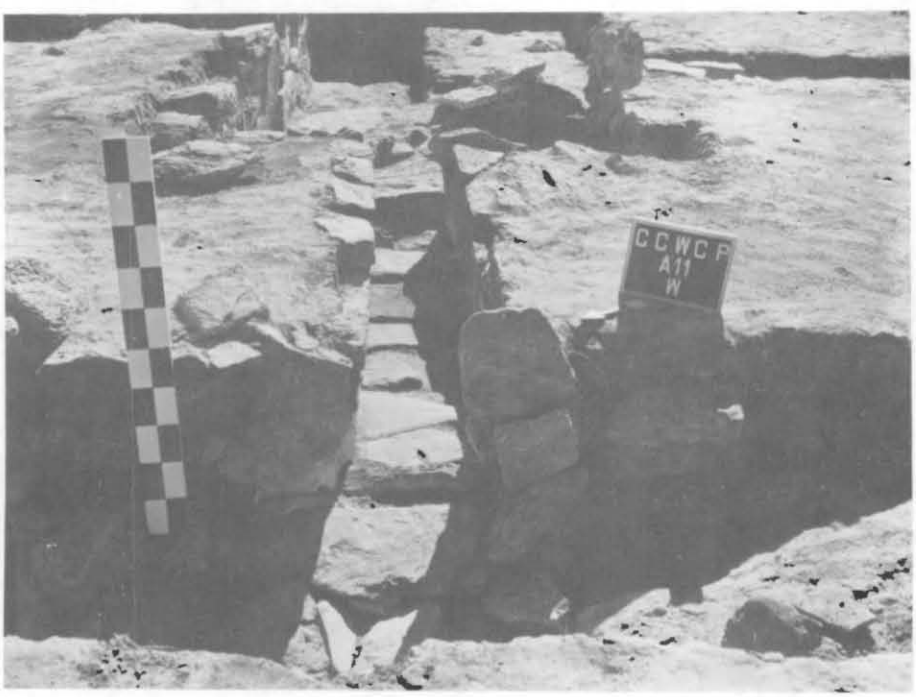


Figure 7. North gate at Peñasco Blanco gate complex from the north. Note flagstone paving of channel and other gates in background (courtesy R. Gwinn Vivian).

distance on either side of the gate openings. The eastern gate at the Penasco Blanco complex has large sandstone slabs covering the upper end of the masonry channel so that a completely enclosed tunnel is created. It is not clear whether these three structures were all used at one time or were used sequentially. Gwinn Vivian (n.d.) found evidence of multiple uses but articulation between the three at any time was obscure. Were all three used together, the central area might have functioned as a small reservoir with inflow controlled by the east and north gates and outflow by the west gate.

Test excavations of the ditch or canal also show a complicated situation with multiple channels and variable construction (slab pavement, rock alignments, masonry walls, or nothing at all). Figure 8 shows a stratigraphic section at one location where a 1-m-high masonry wall has been built on the downhill side of the ditch and at a right angle to the surface runoff from the cliff/slick rock area to the east. Here, probably two channels postdate construction of the wall, both near its base. The more distinct channel has been used here to estimate volume of flow being directed toward the gate complex.

The full extent of the ditch system and drainage area being utilized are uncertain. Gwinn Vivian (n.d., 1974) suggests that water was diverted from the large 'Rincon-4' drainage some 200 m to the north (point B on Figure 4). Flow was then directed either on or along the base of a low irregular terrace of colluvium and Pleistocene gravel (identified as 'upper' and 'lower' alternatives on Figure 4). These alternatives are shown in longitudinal profile along the canal line in Figure 9. There are reasons, archaeological, geological, and hydrological, to question both of these alternatives. Instead, the possibility that only more local runoff (no farther north than point A on Figure 4) was diverted to the gate complex is considered plausible. For the purpose of the modeling presented here, only this last possibility is considered.

A site visit was required to collect data describing the watershed. Data collected included slopes, soils data, and ground cover information. The drainage area above the gate is shown in Figure 4. The area draining into the canal and gate structure was delineated and measured using planimeter techniques (Figure 10). The drainage to the gate was assumed to consist of the surfaces (WS1L, WS1R, Figure 10) draining into the channel that enters the canal at point A, and the surface to the east (PL1, Figure 10) draining directly to the canal. Flow in the major drainage to the west (near B, Figure 4) was not simulated.

Onsite inspection and aerial photography indicate that at least half the drainage is slick rock with little or no soil cover. The soil present is sandy and supports only sparse vegetation. Sandy soils usually have high infiltration rates. Field measurements of nearby similar soils, and Soil Conservation Service soil survey data indicate that the hydraulic conductivity of the soil is about 1.3 cm/hour. Cover also affects overland flow resistance. Due to the large fraction of slick rock and sparse vegetation, the resistance to overland flow for the Chaco watersheds is small.

The watershed model simulated flow from the drainage as a combination of overland and channel flow into the lateral channel leading to the gate. Using the approach outlined under Assumptions And Model Description (above) the drainage was subdivided into two basic units, the first of which is an overland flow plane (PL1, Figure 10) from which overland flow runoff was collected directly by the ditch. The remainder of the drainage was modeled as an open book subwatershed (WS1L, WS1R, Figure 10) with a swale channel that flows into the ditch.

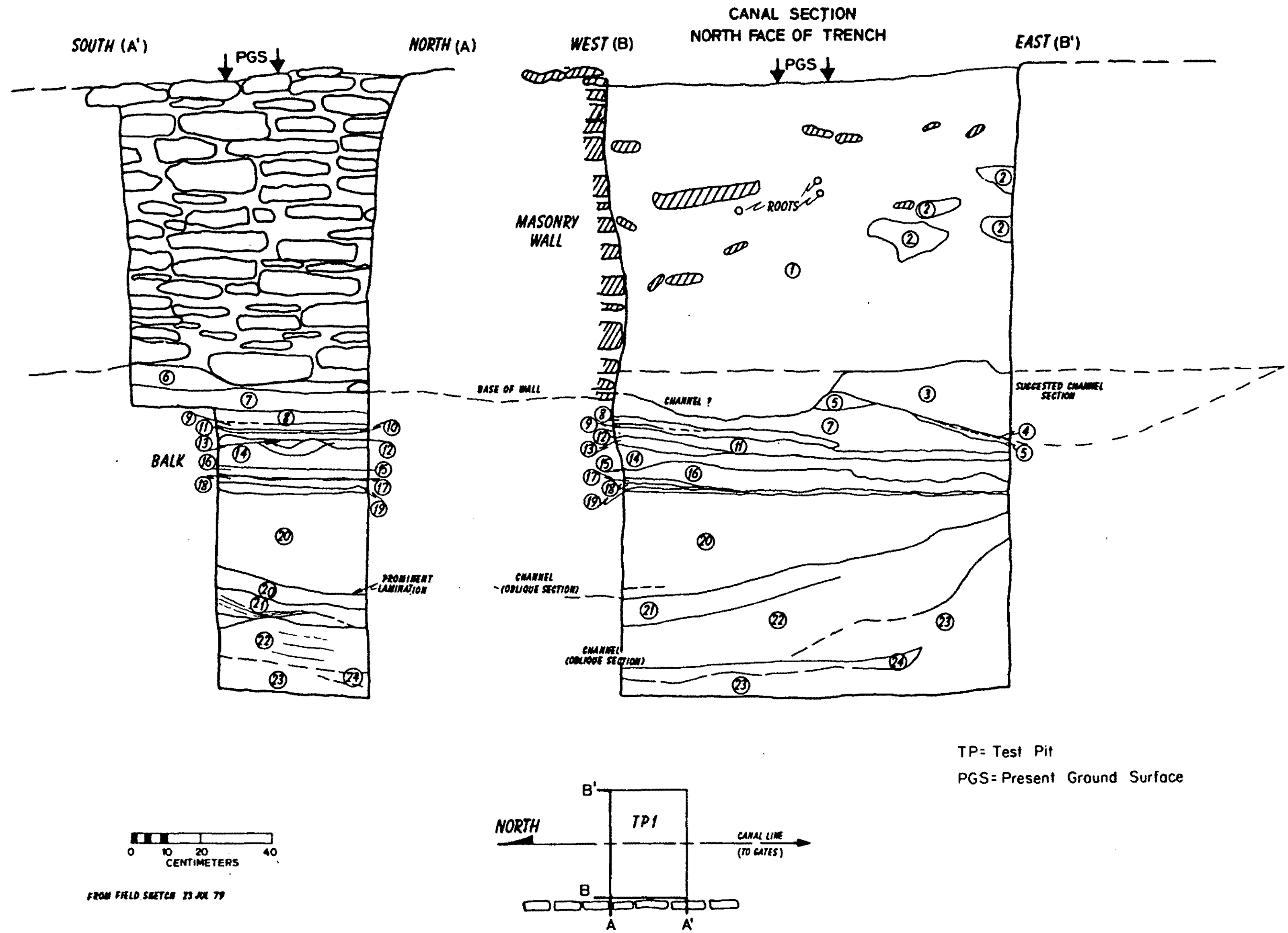
Geometric relationships for the ditch were determined from the suggested channel cross section shown in Figure 8. The relationships are power laws for top width (T_w), cross-sectional area (A), and wetted perimeter (P) as a function of depth, as well as wetted perimeter and top width as a function of cross-sectional area. These relatinships allow the discharge in the channel to be expressed as a function of flow cross-section areas or depth of flow. The expressions for cross-sectional geometry are obtained by computing the parameters from cross-sectional data and performing logarithmic linear regressions to obtain power law fits. The derived expressions are as follows:

$$A = 1.24y^{2.22} \quad (9)$$

$$P = 3.04y^{1.23} \quad (10)$$

$$T_w = 2.48y^{1.27} \quad (11)$$

Figure 8. Stratigraphic sections of canal at Peñasco Blanco (Site A-10) showing channels both predating and in association with masonry wall constructed on downhill side of canal line. Geometric relationships used in modeling channel routing are derived from "suggested channel section." Location of sections are at TP 1 (Test Pit 1) on Figure 4.


CANAL SECTION
NORTH FACE OF TRENCH
SOUTH (A')
NORTH (A)
WEST (B)
EAST (B')
PGS
MASONRY WALL
ROOTS
BASE OF WALL
CHANNEL ?
SUGGESTED CHANNEL SECTION
BALK
PROMINENT LAMINATION
CHANNEL (OBLIQUE SECTION)
CHANNEL (OBLIQUE SECTION)
TP= Test Pit
PGS= Present Ground Surface
0 10 20 40
CENTIMETERS
FROM FIELD SKETCH 23 JUL 79
NORTH
TP1
CANAL LINE (TO GATES)
B'
B
A
A'

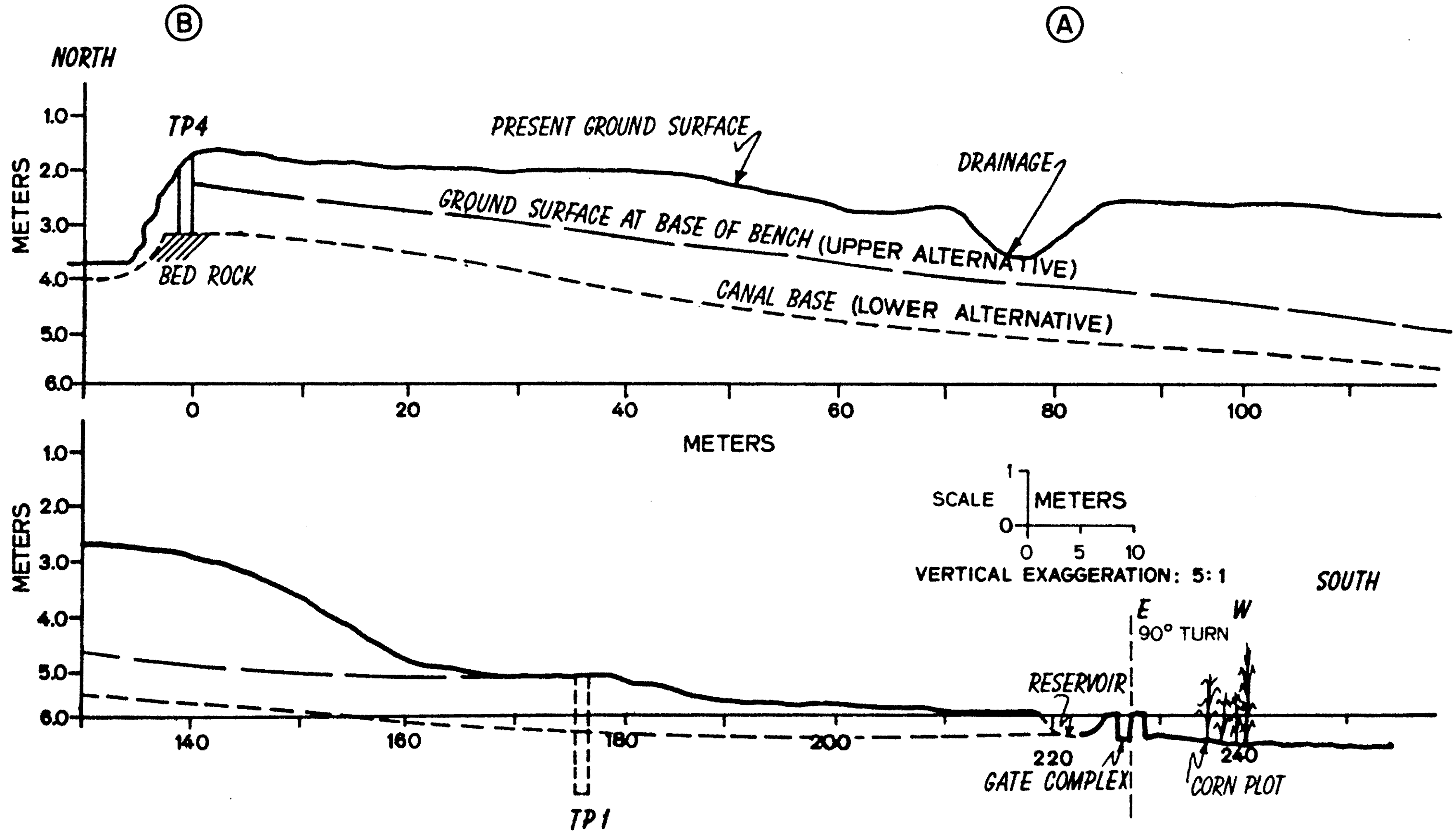


Figure 9. Longitudinal section of possible canal lines at Peñasco Blanco water-control system. Points A, B, and TP 1 show locations on Figures 4 and 10.

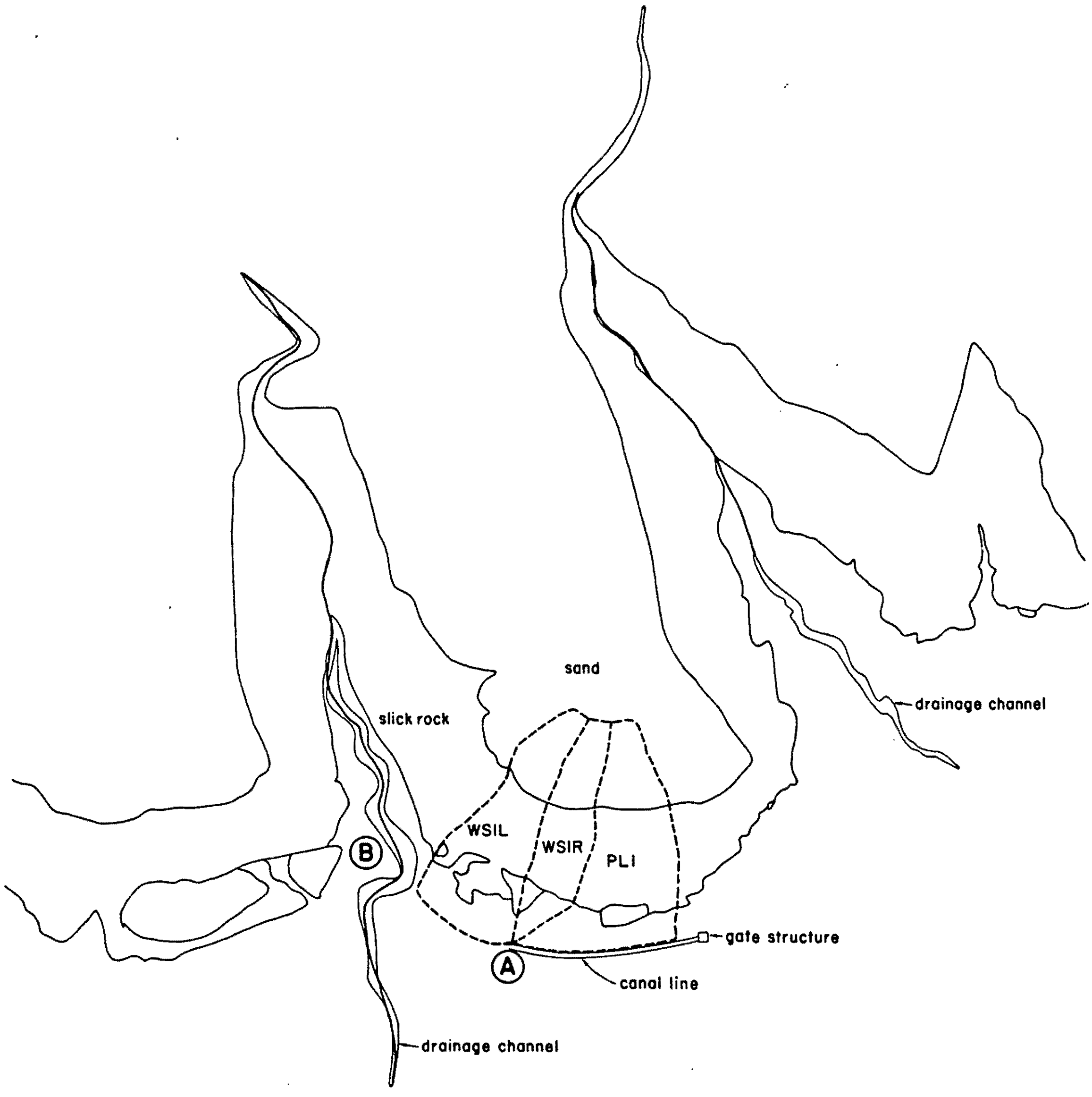


Figure 10. Watershed delineation at Peñasco Blanco water-control system.

$$P = 2.69A^{0.55} \quad (12)$$

$$T_w = 2.19A^{0.57} \quad (13)$$

Note: These expressions are derived in British (fps) units.

While the channel section is partially synthesized, the above expressions are entirely consistent with those found in modern drainage systems. The slope of the ditch was estimated as 0.025 meters/meter from excavation measurements (Figure 9).

As stated earlier, two storms were modeled for this system. The discharge hydrographs (cubic meters per second of flow versus time) of Figure 11 summarize the results for the storms. Probably the most important result is the peak discharge at the gate complex for each event. The peak flows are shown in Table 2. Again the short, high intensity storm is an attempt to approximate a typical thunderstorm. Its return period is approximately one year, and a twenty-minute duration is reasonable for a small summer storm in this region.

Some interesting observations may be derived from the results of this simulation. First, the peak flow of the "typical thunderstorm" is approximately 0.09 cubic meters per second. Calculations using Manning's equation with gate dimensions and a reasonable roughness coefficient indicate that the bank full discharge of the gate opening is also about 0.08 m^3/sec, suggesting that the gate was capable of handling flows from such a "typical" summer event and smaller events.

Farrington (1980) discusses hydraulic characteristics of remarkably similar structures in the mountains of Peru. Here, short channels comparable in size to the Chaco gate structures served as offtakes from a large canal. Farrington suggests that these probably diverted small discharges on the order of 0.003 m^3/sec with depths of no more than three to five centimeters. An important difference, however, is that the Peruvian case involves irrigation from a permanent water source by a low gradient canal, while at Chaco diversion is of sporadic, relatively high intensity runoff events.

The time to peak for this storm is roughly 14 minutes from the beginning of rainfall. This suggests that there was very little time to react to the rainstorm if any operation of the gate was intended. Earlier the possibility that flows were diverted from the major drainage to the north was noted (B, Figure 4). The results of this analysis suggest that the canal and gate system is sized approximately for flows occurring on the modeled watershed area and from small storms such as those modeled. Therefore, from a hydrologic and hydraulic standpoint it appears unlikely that diversions were made from the large channel into the canal or to the gate structure. Alternatively, if diversions were made from the large drainage it appears likely that they were made into a separate system.

Weritos Rincon

As noted above, the large structure just below the mesa top in Weritos Rincon is thought to have functioned as a reservoir, presumably for the domestic use of the nearby mesa top site of Tsin Kletzin. Accordingly, the structure is probably contemporary with the occupation of that site in the A.D. 1100s. The dam was first described and mapped by Gordon Vivian (n.d.) in the 1960s (Figure 12), but no testing has been done.

The main structure is of massive masonry and rubble construction. It was over 40 m in length and enclosed an area of about 600 m^2 (Gordon Vivian n.d.) at the back of an alcove in the uppermost cliff-forming sandstone. In cross section the dam shows multiple components. The initial construction of the west side facing the reservoir is 1.70 m thick and at least 2.40 m high. Subsequent to this construction at least two cruder buttressing walls of rubble and sediment were added to make a total thickness of over 6 m. Two smaller walls are located several meters downstream to the east, but their function is uncertain.

Two questions that may be addressed with hydraulic simulation are:

1. How does the estimated storage volume compare with local runoff hydrology?

2. How much sediment is delivered by runoff to the pool, and what does this indicate about maintenance requirements or the useful life of the structure?

The storms modeled in this case are the same as those chosen for the Penasco Blanco canal and headgate. However, the

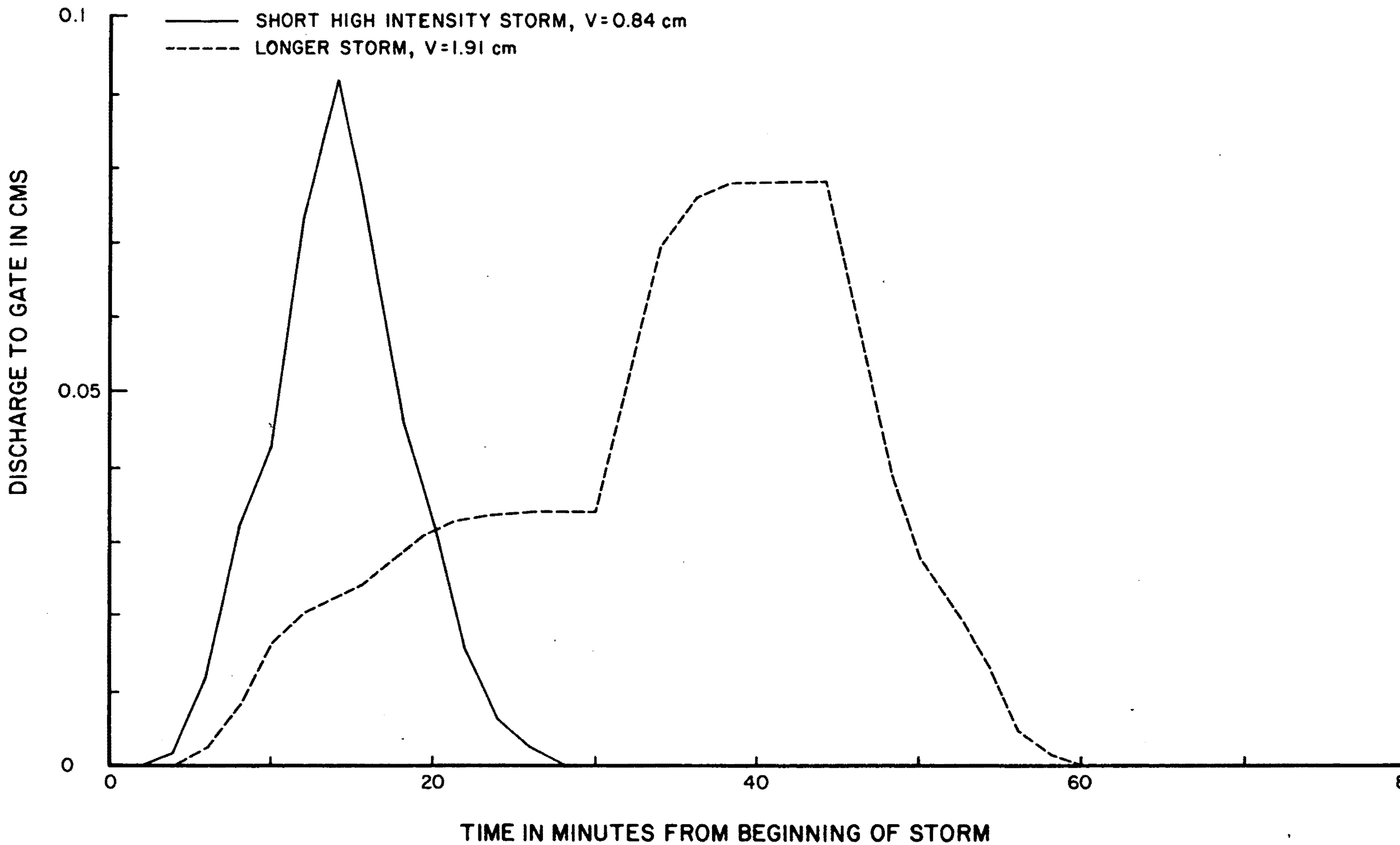


Figure 11. Runoff hydrographs at Peñasco Blanco gate complex.

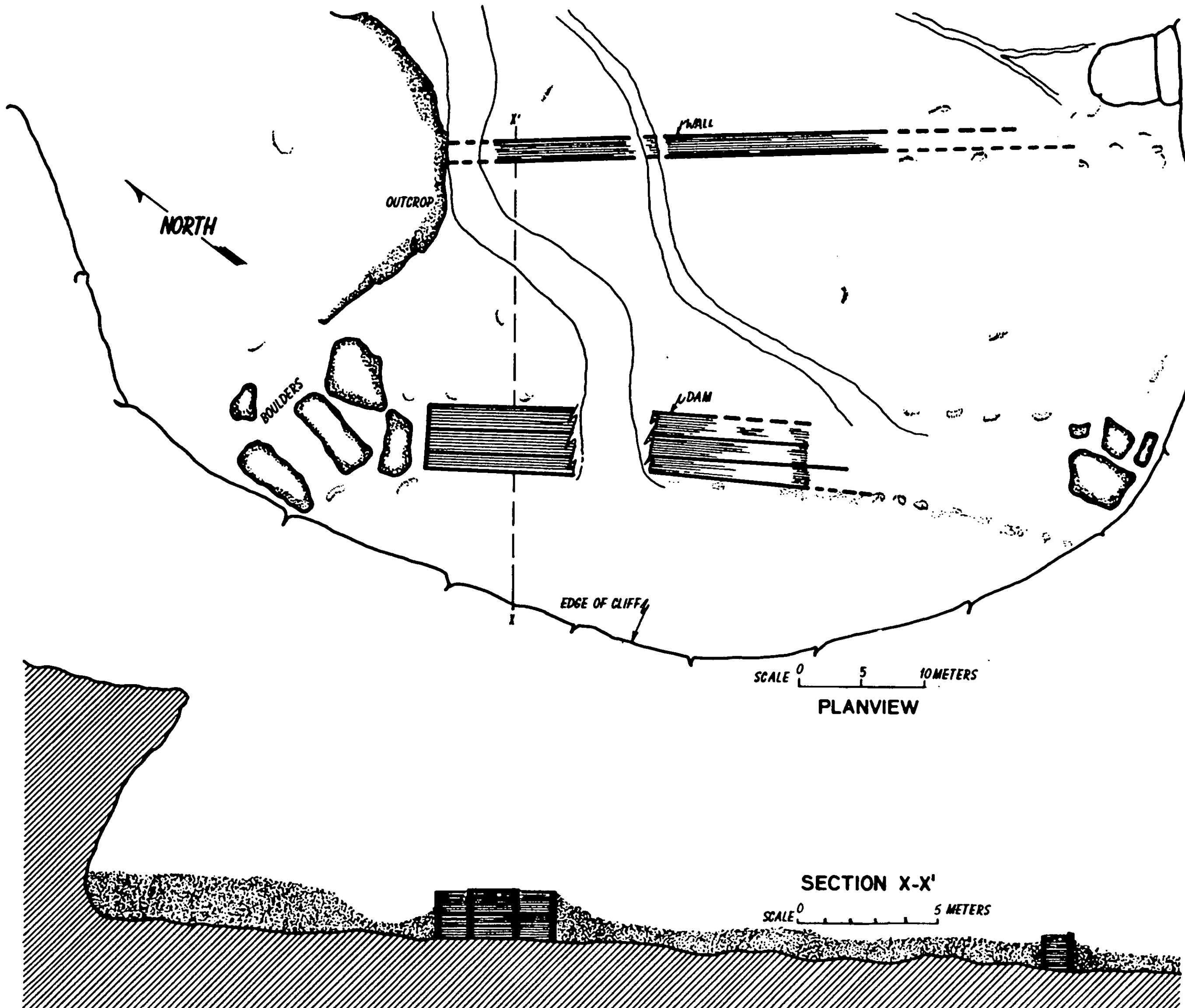


Figure 12. Plan view and section of Weritos Rincon Dam (original by R. Gordon Vivian).

watershed above Weritos is different in character from that above the Penasco Blanco system. The watershed is about 16.1 ha in size and collects much more rainfall. Most of the drainage is covered by a sandy soil with an infiltration rate estimated to be 1.3 cm/hour. The drainage is much more regular in shape and was modeled using a single two-plane segmentation and included channel representation. The channel was assumed to be a swale, which corresponds well with field observations. As at Penasco Blanco, slopes, soils and ground cover data were taken during a field reconnaissance. While the simulation for the Penasco Blanco site considered only the runoff and movement of water through the system, the modeling for the Weritos site was expanded to consider the production of sediment from the watershed and its transport through the swale to the dam site.

Sediment yield is calculated for the planes of the multiple watershed model by comparing detached sediment with the transport capacity of overland flow. The yield is calculated by size fraction and redistributed back over the overland flow water hydrograph to form an overland flow sediment hydrograph. Like the water hydrographs, these are added to form the lateral inflow to the primary channels. In the primary channels the same basic approach is used to produce a sediment yield at the downstream boundary of the channel. Again, the sediment yield is redistributed back over the water hydrograph.

In the main channel, the sediment continuity equation is formulated as a finite difference problem. The sediment continuity equation is used in the following one-dimensional form

$$\frac{\partial G_{si}}{\partial x} + \frac{\partial C_i A}{\partial t} + (1 - \lambda) \frac{\partial P Z_i}{\partial t} = g_{si} \qquad (14)$$

in which i is the size fraction index and denotes the ith size fraction in all terms, G_{si} is the total sediment transport rate by volume per unit time, C_i is the sediment concentration by volume, Z_i is the depth of detachable bed, P is the wetted perimeter, λ is the bed porosity, and g_{si} is the lateral inflow of sediment to the channel from overland flow. The mechanics of main channel sediment transport for this simulation first appeared in Li (1974). Modification of the main channel model for transport by sediment size fraction was made by Simons and others (1977b).

Calculations of sediment transport and erosion are based on the hydraulics of overland flow. After the calculation of overland flow hydrographs is complete, the discharge hydrograph at the downstream boundary provides the information necessary to calculate the sediment yield by particle size fraction. As discussed before, the sediment yield is determined by comparing the detachable sediment with the transport capacity of the flow. Sediment transport is calculated using the Meyer-Peter, Muller equation (USBR 1960) for bed load and Einstein's (1950) suspended sediment formulation. Sediment supply is assumed to arise from detachment by raindrop impact and detachment by the tractive shear of the flow on the watershed. Both detachment methods are empirical and result in the calculation of a nonporous volume of available loose soil for transport. Total transport capacity is found by integrating the weighted (by bed material size distribution) sum of the calculated capacities through the runoff period. The total capacity is converted to a nonporous volume and compared to the available sediment. A determination of whether sediment runoff is capacity or supply controlled then follows to establish the volume of sediment yield.

A sediment hydrograph, either for the overland flow plane or the primary discharge channel, is then constructed by redistributing the volume of sediment yield back over the water hydrograph using the ratio of the increment of water runoff during each Δ t to the total volume of water runoff as a weighting function. The overland flow sediment hydrograph serves as lateral input to the primary channel routing scheme in the case of a two-plane subwatershed or as lateral inflow to a main channel segment in the case of a single-plane subwatershed. A detailed discussion of the mechanics of sediment transport is beyond the scope of this paper; the reader is referred to the above references for greater detail.

With the model applied for both water and sediment routing, the resulting storm runoff can be estimated as shown in Table 3. As at Penasco Blanco, the smaller storm produces a high peak discharge; however, the duration of the peak is short. Therefore, the sediment yield from the small storm is much lower. This analysis also shows the sediment transport power of a small, intense rainfall event. The small event deposited approx-

Table 1. Storm hyetographs.

Time (min)	1.91 cm. Storm Rainfall Intensity (cm/hr)	Time (min)	0.84 cm. Storm Rainfall Intensity (cm/hr)
15	1.23	5	1.65
30	1.75	10	2.39
45	3.66	15	4.98
60	0.91	20	1.24

Table 2. Peak flows at Penasco Blanco gate structure.

Storm Volume (cm)	0.84 (20 min)	1.91 (60 min)
Peak Discharge cms	0.091	0.078

Table 3. Weritos Rincon runoff values.

Storm	0.84 cm (20 minutes)	1.91 cm (60 minutes)
Peak dicharge (cms)	1.25	1.29
Total water yield (m^3)	481	1,470
Sediment yield (kg)	10,100	30,000

imately 10,100 kg of sediment above the dam, while the larger event deposited about 30,000 kg. These quantities of sediment correspond in volume to 6.3 m^3 and 18.6 m^3, respectively (assuming a porosity of 0.4).

The volume behind the dam has been estimated to be approximately one acre-foot (Gordon Vivian n.d.) or about 1233 m^3. The dam has been breached, and over the years pouroff water has had ample opportunity to erode sediments that were deposited when the dam was in use. Also, the Weritos Rincon site is characterized by active deposition of wind blown sand. Consequently, it is difficult to assess the volume of sediment that accumulated behind the dam during the period of its use. Using Vivian's estimate and ignoring the processes of aeolian deposition, it would require between 60 and 190 such storms to fill the reservoir behind the dam. This number of storms could reasonably be expected to occur in 15 to 25 years. Without clearing, this period probably represents an upper limit on the operational life of the structure. Further, the neglected aeolian transport would probably significantly shorten the time required to fill the pool. Utility of the structure could not have lasted long without maintenance and probably did not last long after abandonment.

Perhaps of greater importance, water yield computations indicate that while the dam was probably adequate to handle small events, it would be overtopped by larger events occurring on the average as often as every two years. Overtopping would become progressively more likely as sediment filled the reservoir pool. This process would probably cause the dam to breach, assuming there was no hardened spillway. Therefore, it is reasonable to conclude that the dam was either a short-lived project or required considerable rebuilding and possibly sediment removal between rainfall events. The addition of buttressing at least twice after the initial construction of the dam and differences in construction details on either side of the present breach may be evidence of prehistoric breaching and repair.

Conclusions

This paper has presented a relatively sophisticated model of small watershed runoff and channel routing in an attempt to better understand the hydrologic and hydraulic characteristics of prehistoric water-control structures in Chaco Canyon. This is largely a trial application aimed at illustrating the utility of these methods to archaeological research problems.

In the Southwest, as elsewhere, archaeologists and ethnographers have long been interested in water control systems and have frequently attached major social implications simply on the basis of its presence (e.g., Wittfogel and Goldfrank 1943; Vivian 1970; Grebinger 1973). However, many conclusions and implications have been reached without adequately understanding how such systems functioned. For example, Ford (1977) and Farrington (1980), on the basis of ethnographic observation in New Mexico and Peru, respectively, have recently challenged the widely held view that irrigation necessitates centralized authority because of large maintenance requirements. Both found that maintenance efforts were not extensive and did not require any centralized authority associated with large maintenance requirements. Data presented here from Weritos Dam suggest that, in the runoff-based water control practiced at Chaco, more maintenance effort may have been necessary for some structures. Here, up to 30,000 kg, or 18.6 m^3, of sediment deposition and possible structural damage can be expected with peak flows. Still, the amount of labor required is not excessive (18 m^3 is smaller than many pithouses), and there is no compelling reason to interpret these requirements as implying any centralized organization of labor.

Application of these modeling techniques to the small agricultural systems described by Vivian (1974) suggests that they are of a size well suited to diversion and utilization of local runoff events. These data also suggest that the structures operated in much the way described by Vivian but were probably not capable of handling runoff from the major lateral drainages as suggested by Vivian (1974). Instead, the Penasco Blanco complex and other ditch/gate structures appear better suited to utilizing runoff from much smaller watersheds situated between the major tributary drainages.

Application of hydrologic and hydraulic modeling techniques can improve our understanding of how prehistoric water-controlled systems functioned. These techniques are applicable in a variety of situations and can be used to model responses to a variety of different inputs and conditions. In this initial study, modern parameters have been used and assumed applicable to the past. However, the potential exists for investigating system response to different precipitation inputs and different watershed variables such as soil and vegetation characteristics. Thus, there is considerable potential for better understanding of prehistoric adaptation to local environments.

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DIVERSITY, STABILITY AND THE DEER MOUSE: IMPLICATIONS FOR THE VEGETATIVE DIVERSITY MODEL

Jack F. Cully, Jr.

Abstract

The effect of alpha diversity of plant communities on the stability of deer mouse populations was studied at four trap grids at Chaco Canyon, New Mexico. Perennial vegetation cover was measured by the line intercept method, and cover and diversity were calculated from these data at each habitat. Deer mouse populations were least stable in habitats with high diversity and most stable where diversity was low but cover was high. There is some evidence that deer mice are responding to beta (or between habitat diversity) by dispersing offspring into a variety of habitats. I call this the beta diversity model. A review and reanalysis of some archaeological literature indicates that prehistoric human populations may also have used beta diversity as a factor in locating settlements.

Introduction

Archaeologists have frequently borrowed ecological theories in an effort to explain human subsistence and settlement patterns. One ecological factor that has been used to predict settlement patterns is vegetative diversity. Chapman (1979) refers to this as the vegetative diversity model. He says that "A basic tenet of this model is that archaic residential locales will be located in areas of the highest ecological diversity" (1979:75). With the exception of this paper, archaeologists have not explicitly considered the scale of diversity that should be measured (Plog and Hill 1971; Judge 1971; Hill 1971; Allan and others 1975; Reher and Witter 1977). These papers did not specify any methodology for determining diversity; they were derived from economic rather than ecological theory.

The idea that high ecological diversity is desirable was first articulated by MacArthur (1955). He develops a simple model that predicts that increasing the number of energy pathways from low trophic levels through the top carnivore would increase community stability. He suggests that an index of stability would be expressed by the Shannon-Weaver diversity index

$$H' = -\Sigma P_i \log P_i$$

where P_i is the proportion of the community belonging to species *i*. Margalef (1963) replaces diversity of energy pathways with diversity of plant species, which makes data collection simpler. This is the diversity-stability hypothesis.

May (1973, 1974) shows theoretically that more diverse trophic systems are less stable than simple systems. Goodman (1975) reviews the diversity-stability concept and argues that there is little theoretical support for the idea that community diversity enhances community stability. There is little direct empirical evidence, however. Consequently, one of my research questions at Chaco Canyon was whether deer mouse populaton stability is related to local plant diversity. Deer mice (*Peromyscus maniculatus*), like humans, are generalist foragers and perhaps can shed some light on the scale at which diversity should be examined.

In this paper, diversity refers to the number of plant species equivalents calculated by Simpson's diversity index $1/\Sigma P_i^2$ (Simpson 1949). This is more amenable to statistical analysis than the Shannon-Weaver index, and it is more easily interpretable. For example, if the community is composed of four equally abundant species, the diversity = 1 / 4 $(.25)^2$ = 4 species equivalents. If one species accounts for 85% and the remaining three account for 5% each, the diversity = 1 / $(.85)^2$ + 3 $(.05)^2$ = 1.37 species equivalents. The diversity that I measured is within habitat, or alpha diversity (see Whitaker [1972] for a discussion of different scales of diversity). Beta diversity measures the rate of species turnover between habitats in a larger area, and it may be important to animals in different ways than is alpha diversity. Beta diversity is most simply computed for a two habitat system by the formula $CC = 2S_T/(S_1 + S_2)$ where CC is a coefficient of community, S_T is the total number of species observed, and S_1 and S_2 are the number of species in habitats 1 and 2 (Whittaker 1972). This formula will not work when beta diversity needs to be calculated for more than two samples, as will almost always be the case in catchment analysis. To measure beta diversity in a catchment area, samples of vegetation cover or density can be taken in a random or stratified random manner and analyzed by a computer clustering program. If the same number of samples are taken in each catchment, the average distance of the cluster containing all points will provide a relative measure of beta diversity. Beta diversity, then, is an index of overall vegetative change between habitats and is independent of alpha diversity.

Stability is more difficult to define. In this paper, I consider the role of plant community diversity as a stabilizing influence on deer mouse populations rather than on the rodent community as a whole. This is also how archaeologists use diversity-stability theory in the vegetative diversity model. Stability is then correlated with minimum population density. In other words, a population that remains consistently large is more stable than one that occasionally is reduced to low numbers.

Methods

The work reported here was done between October 1978 and June 1981 at Chaco Culture National Historical Park. I trapped five permanent one-hectare trap grids in four habitat types. Since I do not have vegetation data for the pinyon-juniper habitat, that habitat is not included in this report. Each grid consists of 100 trap stations in a 10 x 10 grid. Intertrap spacing is 10 m. The traps are 9 x 10 x 27 cm Sherman aluminum live-traps baited with oatmeal. When mice are caught they are identified to species, sex, age, and are individually marked with numbered aluminum ear tags or by toe clipping. They are then released at the point of capture. Populations are estimated by Schnabel analysis (Tanner 1978), a multiple mark recapture technique. Each trap grid was trapped during six sessions, three four-night sessions and three three-night sessions, yielding a total of 8,400 trap nights.

Perennial shrub and grass cover was measured using the line intercept technique (Canfield 1941). Associated with the trap grids at each habitat is a 1.6-km transect marked with stakes at 31-m intervals. Perennial cover was measured by running a 10-m line perpendicular to the transect from every other stake. This yields 250 m of intercept data. All perennial vegetation under the line was measured by species to the nearest centimeter. Total cover was then calculated as the percentage of vegetation under the line. Diversity was calculated on the amount of cover contributed by each species using Simpson's diversity index.

In a separate study (A. Cully and J. Cully in prep.) annual plant data were collected at three of the trap grids and near Pueblo Alto. Annual plant density was estimated by counting plants in 20 plots measuring 1.0 x 0.5 m, located at regular intervals at the Pueblo Bonito, Casa Chiquita, and bench grids as well as near Pueblo Alto (see study area descriptions below). Annual vegetation was measured during June 1979, 1980 and 1981. In addition to counting plants, they were picked at each plot to estimate both dry weight biomass and the weight of seeds produced. Since annuals are ephemeral, diversity indices were not calculated for them.

Study Area Descriptions

The locations of habitats and trap grids are presented in Figure 1. The blank areas are the shrub grassland outside of the canyon; I did not trap that habitat. The first habitat is the bench, which is characterized by low shrubs, bunch grasses, and extensive areas of exposed sandstone. The Casa Chiquita and Pueblo Bonito grids are located on the floodplain. These two grids are both dominated by black greasewood (*Sarcobatus vermiculatus*) and four-wing saltbush (*Altriplex canescens*). Kelley and Potter (1974) consider these two areas to be the same vegetation type, but Pueblo Bonito has higher cover and the shrubs are larger. The wash contains groves of Cottonwood trees (*Populus fremontii*), thick stands of willow (*Salix exigua*) and salt

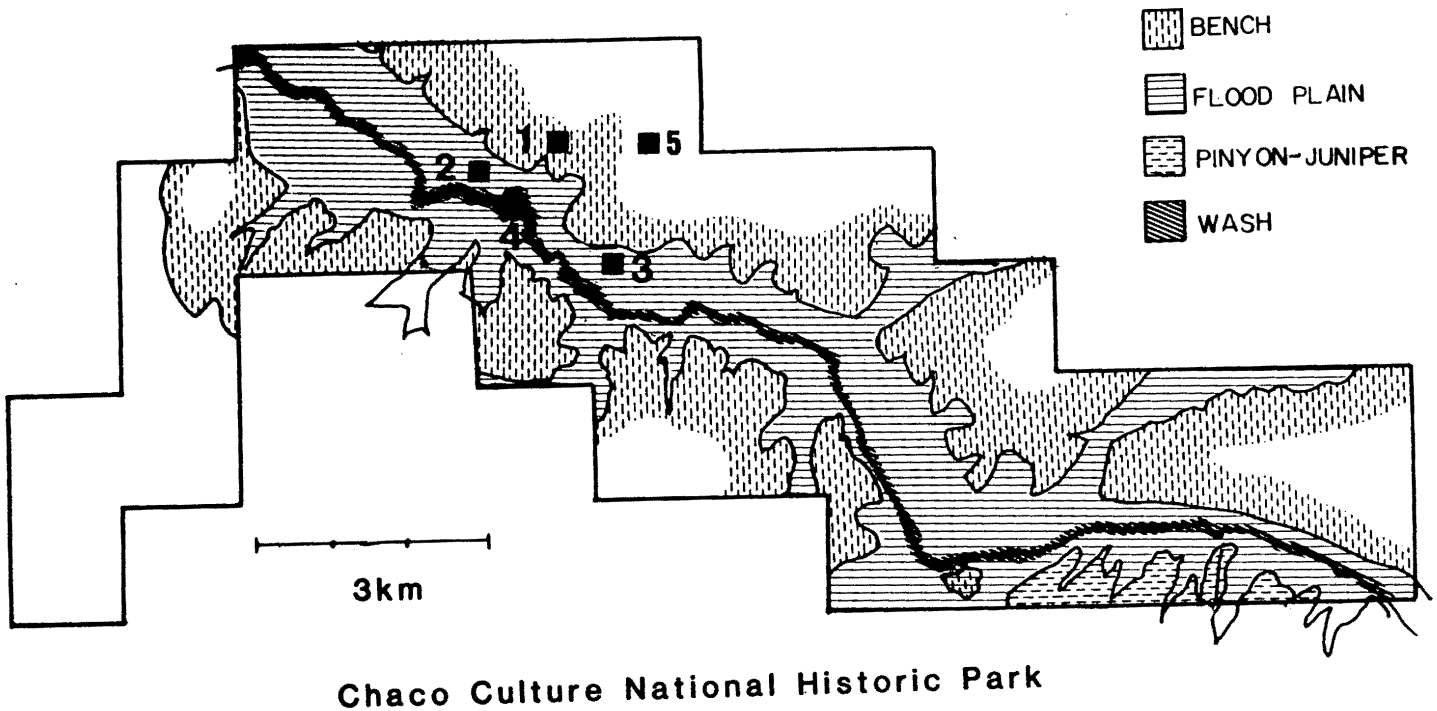

Figure 1. Habitat types at Chaco Canyon with locations of trap grids and vegetation sampling areas: 1 bench, 2 Casa Chiquita, 3 Pueblo Bonito, 4 wash, 5 Pueblo Alto.

cedar (Tamarix sp.). The habitat at Pueblo Alto consists primarily of grasses with small four-wing saltbushes.

Results

The results of the diversity analysis are presented in Table 1. The most noticeable feature is the lack of correlation between cover and density. The bench has the lowest cover (16%) and the highest diversity (6.3). The wash has the highest cover and the second highest diversity. Casa Chiquita and Pueblo Bonito both have lower diversity and intermediate levels of cover.

The annual seed and foliage production measured are presented in Figure 2. The important feature of these data is that there is no correlation of productivity across habitats through time. The maximum productivity during the three years was at the two floodplain sites in 1979. This reflects a tremendous production of pinnate tansy mustard (Descurania pinnata), which was not found at the other grids. During 1980 and 1981 the floodplain grids had the lowest productivity. The bench and Pueblo Alto both had higher productivity in 1980 than in 1979, and in 1981 Pueblo Alto was the only area with measurable seed production. The food for mice produced by perennials along the floodplain and the wash probably exceeds that produced at the bench and at Pueblo Alto during years of poor annual productivity, but the large differences between habitats that occurred in 1979 disappeared during 1980 and 1981.

Each of the four grids was trapped once prior to sampling vegetation during 1979 and again at approximately the time of sampling (Figure 3). Deer mouse populations at all four areas declined between these two sessions. Between summer and fall, deer mouse populations grew tremendously at the wash and Pueblo Bonito, but declined at Casa Chiquita. I have no explanation for the decline in population there unless it was a result of sampling error or the result of emigration of mice into the wash. During January, 1979, there was a severe flood that scoured much of the rabbitbrush and grass out of the wash and apparently decimated the resident mouse community. When I trapped there in April 1979, almost all of the mice were deer mice. I trapped a series of assessment lines (O'Farrel and others 1977) around the grid, both in the wash and on the floodplain, to see if the mice I had trapped there occupied home ranges entirely in the wash, or if they extended onto the floodplain. Of the 23 deer mice caught in the wash grid in April, I recaptured 14 one week later. Eight of these recaptures were taken on the floodplain and six from the wash. During June, 1980, I again trapped assessment lines around the wash grid and caught 12 mice that had previously been caught on the grid. Of these, eight were caught in the wash and only four on the floodplain. This might indicate that in October, 1979, the trap results were low at Casa Chiquita because mice were moving into the wash.

During 1979 the spring was very wet and annual plant production was very high; this was mostly a monoculture of pinnate tansy mustard. There was also an abundance of insects and perennial seeds. Conditions seemed to be good for deer mouse reproduction at the two floodplain sites and at the wash. Deer mouse populations were higher in the wash and at Pueblo Bonito during 1979 than 1980, and I suggest that deer mouse populations at those two grids responded to the annual plant production.

The variations in population at each grid reflect increases due to late summer and fall reproduction. The population at the bench grid increased during spring 1980, but most of the deer mice caught there were previously unmarked males (seven males and one female). These mice probaby dispersed out of the adjacent floodplain habitat when resources became scarce there.

To see whether deer mouse populations are associated with diversity or cover, I performed a correlation analysis of the average population at each grid with diversity and with total cover at each grid. Although these correlations are not significant, the signs of the coefficients suggest that deer mouse populations are positively correlated with cover (r = 0.74, df = 2, ns) and negatively correlated with diversity (r = -0.8981, df = 2, ns).

Discussion

It is clear that the high alpha diversity on the bench has not resulted

Table 1. Plant composition and diversity at the four trap grid habitats.

Species	Bench	Casa Chiquita	Pueblo Bonito	Chaco Wash
Agropyron smithii				71
Artemisia biglovii	1195			190
Artemisia tridentata				573
Atriplex canescens	164	187	3829	
Atriplex obovata		1808		
Chrysopsis villosa	27			
Chrysothamnus greenii	200			
Chrysothamnus nauseosus				2953
Chrysothamnus pulchellus	107			
Ephedra viridis	680			
Eriogonum sp.	516			
Eurotia lanata	49			
Gutierrezia sarothrae	10	21		
Hilaria jamesii	327	415		
Lycium pallidum			44	
Muhlenbergia pungens	92			
Opuntia polyacantha	6			
Oryzopsis hymenoides	324		4	80
Populus fremontii				200
Rhus trilobata	79			
Salix exigua				1772
Sarcobatus vermiculatus		1215	2260	
Sporobolus airoides		765	131	

Table 1. (continued).

	Bench	Casa Chiquita	Pueblo Bonito	Chaco Wash
Sporobolus sp.	101			309
Sueda torreyana		286	202	
Tamarix sp.				2179
Yucca sp.	51			
Unknown	24			
% Cover	16	17	28	34
Diversity	6.3	3.3	2.4	4.2

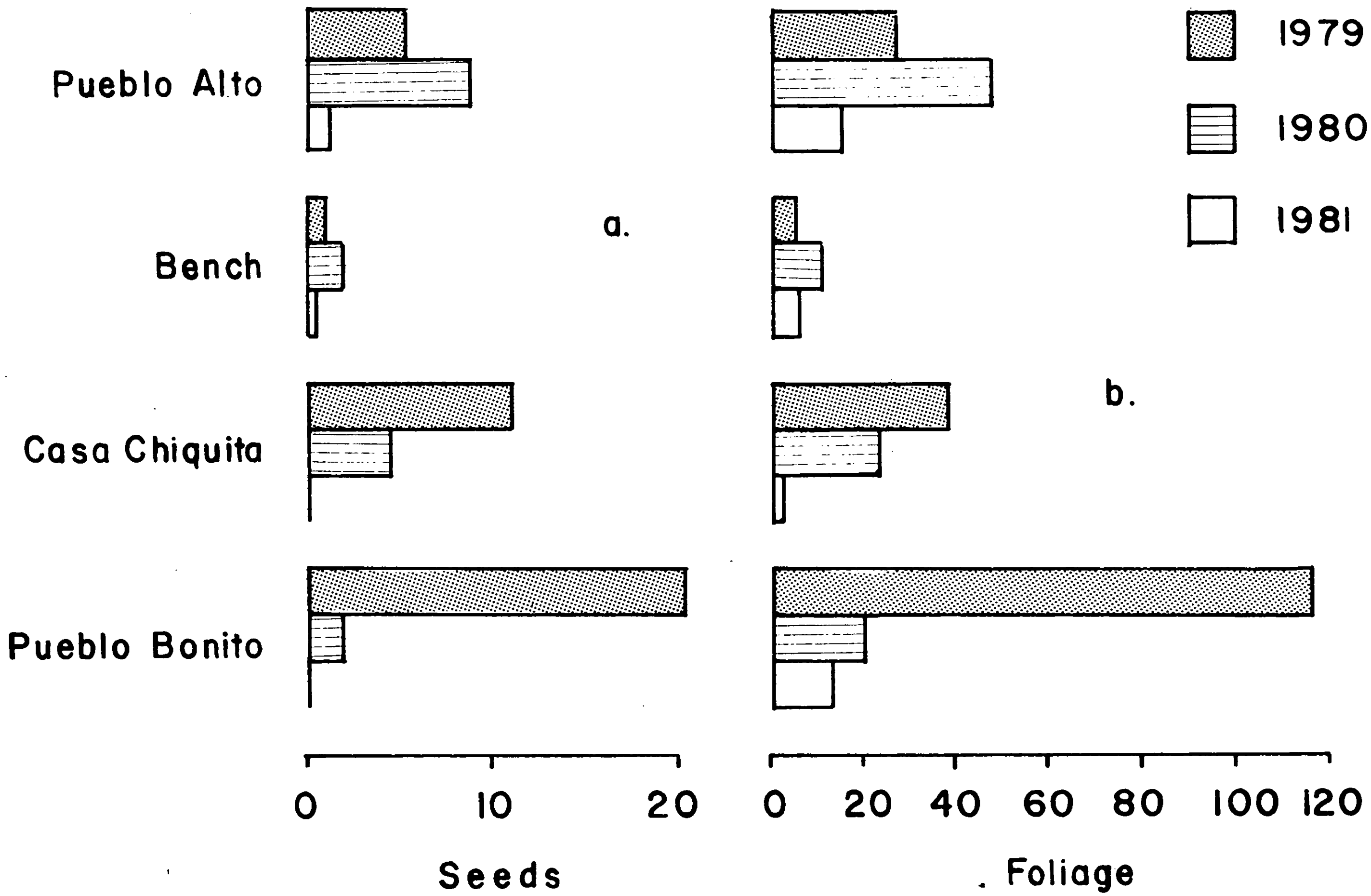

Figure 2. Annual biomass production at four habitats at Chaco Canyon during 1979, 1980, and 1981. Biomass is expressed as gm/m of seeds (a) and foliage (b).

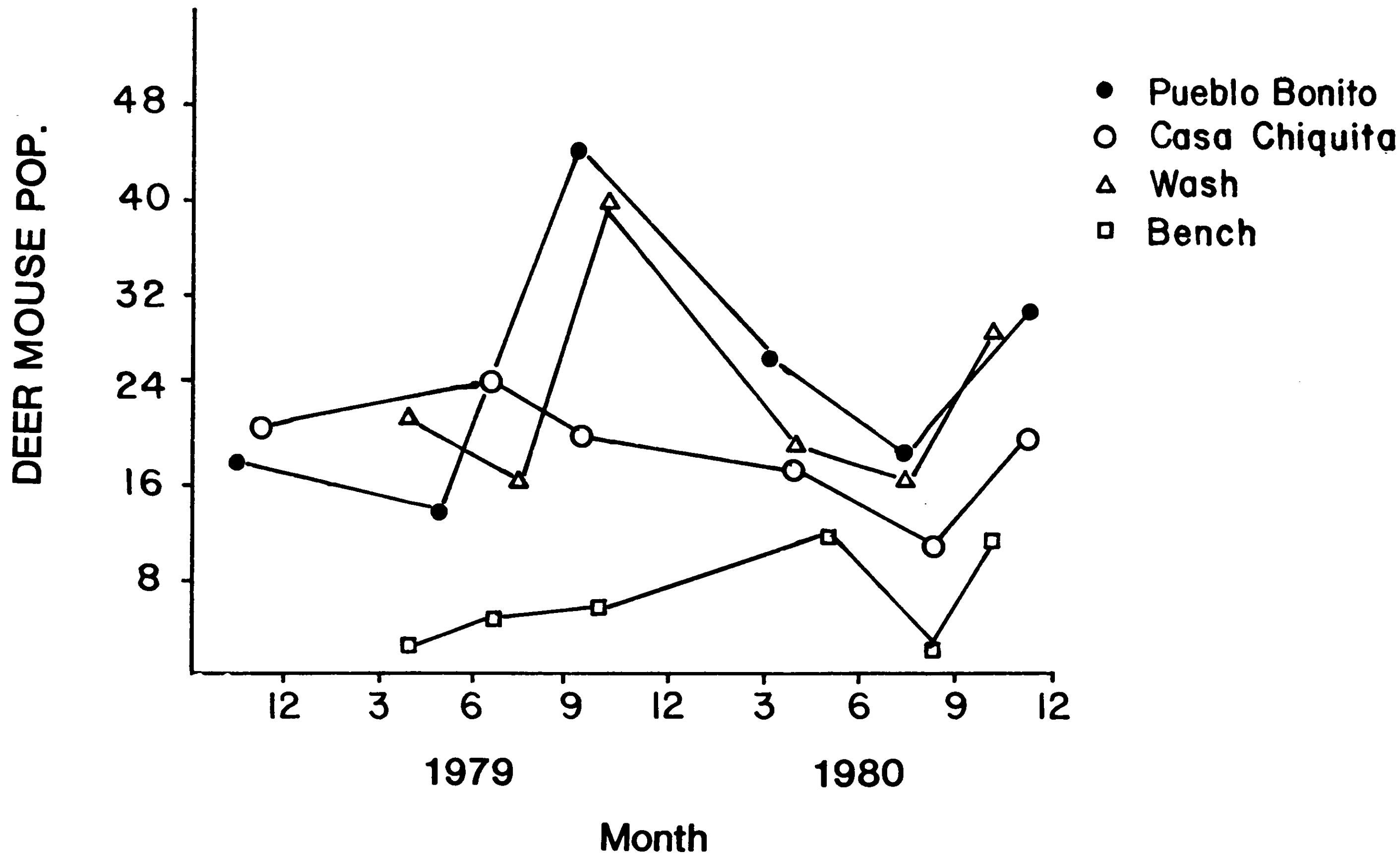

Figure 3. Mouse density estimates at four trap grids during the period October 1978 through November 1980.

in a stable deer mouse population there. The populations on the bench were consistently lower than in the other habitats, which had lower diversity but higher cover and productivity.

An important feature of diversity calculated by either the Shannon-Weaver index or the Simpson index is that if one species becomes abundant and dominates the community, the number of species equivalents is reduced. This accounts for the low diversity found at Pueblo Bonito and Casa Chiquita, where two species account for 88% and 71% of the cover. The kind of productivity seen at Chaco Canyon for brief periods tends to be produced by monocultures of species such as pinnate tansy mustard or Indian ricegrass (Oryzopsis hymenoides). These are the kinds of resources most easily harvested by mice, birds, and probably man. They are certainly the kinds of resources that maximize the benefit/cost ratios for harvesting foods.

The annual plant biomass and seed set data show that the shrub grassland on the mesa top near Pueblo Alto had low productivity during 1979 when conditions were bountiful on the floodplain. Productivity was relatively high there during 1980 and 1981 when the floodplain was producing virtually nothing. The brief deer mouse population increase on the bench followed quickly by a decline suggests that the bench was being visited by transient mice. This raises the possibility that deer mice are diversifying their economies by dispersing young into a variety of habitats, i.e., that they are taking advantage of beta diversity.

A modification of the diversity-stability hypothesis is related to the spreading of risk hypothesis (den Boer 1968). Although this hypothesis was originally couched in group selection terms, it is easily modified for selection at the level of the individual. Despite Goodman's (1975) objections "to folk wisdoms about eggs and baskets" the notion that organisms living in temporally and spatially varying environments should have access to a variety of resources that will be available at different times seems valid.

This hypothesis I call the beta diversity model. The mini-max theory espoused by several authors in Gumerman (1971) has this as an implicit assumption. This is also the reasoning underlying the vegetative diversity model. The beta diversity model does not include the assumptions (Chapman 1979) of the vegetative diversity model, that organisms are fine-grained foragers or that benefits/costs are a positive function of diversity.

For human populations "an important goal guiding economic behavior of hunter-gatherers appears to be the minimization of effort" (Jochim 1976:7; also see Boserup 1965). Helm (in Jochim 1976) suggests that settlement patterns represent a dependent variable where ecological factors are predictor variables. This was the basis for the study design of Reher and Witter (1977), who attempted to correlate Archaic settlement patterns with plant diversity. They assumed that plant diversity was correlated with graininess on aerial photographs. Unfortunately, they made no ground checks to verify this assumption and consequently their data are uninterpretable. They seemed to think that they were measuring alpha diversity and interpreted their results as indicating that settlement was associated with high diversity. An examination of the data in their Figure 3.7 shows, however, that if any relationship exists, it is that settlement is most frequent in areas of low diversity (see also Winter 1980:1).

Chapman (1979) analyzes habitat diversity of catchments surrounding site clusters in White Rock Canyon, New Mexico. His diversity measure was at the beta scale of diversity, although it was not calculated as beta diversity. His analysis considered the diversity of mapped vegetation zones within catchments. This is similar to beta diversity if one assumes that plant communities are composed of coadapted sets of species that change together at vegetation zone boundaries This is usually not the case. Whittaker (1975) reports on plant distributions across an elevation and moisture gradient, and finds that plant species were distributed independently.

Despite this, Chapman's study does provide the best analysis of the vegetative diversity model that I have seen. Although he concludes that vegetative diversity does not predict human settlement, there are several methodological difficulties, largely outside of his control, which may indicate that he was too quick to reject the model. The first problem was that his survey data were from a very restricted area (within the 5460.5-foot contour level in White Rock Canyon). Thus he did not have site data for large areas where he calculated catchment diversity, particularly at the north end of his study area. Second, by being restricted to the canyon bottom, the range of diversity available to test is limited (on the east side of the canyon seven of eight catchments had virtually identical diversity). Third, by calculating diversity of catchments only around known site clusters, he has biased his data in such a way that if there is a correlation between settlements and diversity, it will be diminished in his analysis, since he analyzed no areas without sites. A stronger test would be to randomly locate hypothetical catchments, calculate diversity, and correlate that with the number of sites within the catchment. Unfortunately, at White Rock Canyon, survey data are not available over a large enough area to make this possible.

Despite the shortcomings of Chapman's data, the correlations were in the direction predicted by the vegetative diversity model. I reanalyzed his data using 3-km catchment radii in order to increase the variance in diversity among sites east of the river. The correlation was weakly significant ($\underline{r}$ = 0.6127, df = 9, P<.05), reversing Chapman's findings. This reanalysis of Chapman's data supports the vegetative diversity model.

Conclusions

Plant productivity at Chaco Canyon varies between habitats independent of alpha diversity, and productivity is not correlated between habitats through time. Deer mouse populations were consistently higher in areas of low diversity and high cover than in areas of high alpha diversity. The behavior of populations on the bench, the habitat with the highest alpha diversity, indicates that this habitat might be transitional between the floodplain and the shrub grassland mesa-top. If so, I suggest that mice are taking advantage of, and deriving stability from, beta rather than alpha diversity. I call this the beta diversity model. A brief review of archaeological literature indicates that human hunting and gathering populations may also follow the predictions of the beta diversity model. The most productive foraging sites for human hunter-gathers are likely to be in patches of seed producing plants with very low alpha diversity. If Archaic populations were locating their camps in areas where a variety of resources were available for harvest at different seasons, then these sites should be in areas of high beta diversity. As suggested above, the best areas should also have low alpha diversity.

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TEMPORAL VARIATION IN FAUNAL ASSEMBLAGES FROM CHACO CANYON

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Abstract

Comparison of faunal assemblages at the site level is often biased by the sample size and often results in only one unit of comparison per site. By breaking a site down into assemblages--or provenience groups of elements with sufficient sample sizes--the number of sample units is increased and the intrasite variability may be recognized. Discriminant analysis was performed on 94 faunal assemblages from 10 recently excavated sites in Chaco Canyon. These sites, ranging from Early Basketmaker III to Late Pueblo III, were used to document changes in both the overall and the small mammal subsistence strategies. Testing of time periods by this method allows us to recognize what taxa are contributing to the differences and thus to relate the changes to the broader social and economic picture.

Introduction

In addition to providing a description of prehistoric human use of animal resources, the study of faunal remains can be used to monitor changes in the subsistence strategy. This strategy is affected not only by changes brought about in the local environment by the human interaction but also by changes in the human economy. The results of human use (possibly overuse) of the immediate area, as well as their adaptation given the organizational options available to them, can be seen in the faunal assemblages from 800 years of occupation in Chaco Canyon. In order to address these adaptations it is necessary to identify the changes and begin to ask the appropriate questions.

During the course of the Chaco Project the faunal remains from 12 recently excavated sites were identified. The sites range in time from Early Basketmaker III to Late Pueblo III with sample sizes of under 100 to over 30,000 elements. A number of the sites were multicomponent and spanned several time periods. Table 1 gives a synopsis of the sites for which the quantitative information is available. This includes the number of elements analyzed from each site, the minimum number of individuals (MNI) for the site, the number of species represented at the site, the economic species MNI (species that occur in sufficient numbers and display evidence of processing that suggests use as food items) for the site, and the number of provenience divisions that resulted in the site MNI.

Methodology

Much debate surrounds the question of which measure of taxonomic abundance is best used for further analysis or comparison of faunal materials. Ultimately, the number of elements was chosen over the MNI as the unit of measurement because, as Grayson points out, "MNI values for any series of taxa can be predicted quite accurately from specimen counts for those taxa" (1979:233). In order to be reasonably sure that this is true for the Chaco data, linear regressions were calculated on the figures in Table 1 (Table 2). These suggest that the element count is a good predictor of both the site and the economic MNI and the number of species found at a site. It also suggests that the number of provenience divisions does indeed have an effect on the MNI totals, and that as the sample size increases so does the number of species represented. The latter makes simple comparisons based on radically uneven sample sizes (such as the Chacoan sites) very dubious.

Besides the problem of uneven sample sizes, use of the site as the unit of analysis can mask chronological differences in multicomponent sites. Analysis of a number of samples from a site more clearly indicates patterning that may not show up in a site total. Ninty-four assemblages or excavational units from 10 sites were included in the following analyses (Appendix 1). They were chosen on the basis of sample size and location from within spatially restricted areas in order to increase the likelihood that accumulation had taken place over a relatively short period of time. Each of

Table 1. Quantitative information for the Chaco Canyon sites.[1]

Site	No. of Elements	Site MNI	No. of Species	Economic MNI	No. of Ec. Spec.	No. of Prov. Div.
29SJ423	1964	76	18	60	11	11
29SJ1659	339	48	15	37	12	4
29SJ628	4997	142	25	122	17	11
29SJ299	318	46	14	32	11	9
29SJ724	470	44	16	38	9	10
29SJ1360	708	64	14	54	10	19
29SJ629	2818	334	26	237	15	38
29SJ627	6752	428	24	353	16	71
P. Alto-1*	4864	292	29	240	20	50
P. Alto-2**	15037	700	39	678	30	87
P. Alto-3***	9666	569	37	553	30	52
Una Vida	3374	250	17	163	14	25
29SJ633	3904	270	24	255	15	27

1 sources: Akins 1981a-g, 1982a and b; Gillespie 1981a, b
* Pueblo Alto - Red Mesa Ceramic Association
** Pueblo Alto - Gallup Ceramic Association
*** Pueblo Alto - "Late Mix" Ceramic Association

Table 2. Linear regression results (R^2 for Y=A+B*X).

	Site MNI	# of Species	Econ. MNI	# of Ec. Species	# of Prov. Div.
Number of elements	.88	.84	.97	.87	.76
Site MNI		.84	.95	.82	
Provenience divisions	.87		.82		

these is a distinct unit--generally a layer of trash or floor fill/occupational debris.

The information recorded for each assemblage includes the following: a site code; the time period or "ceramic association"; percentage of the assemblage that was comprised of cottontail rabbit (Sylvilagus sp.), jack rabbit (Lepus californicus), prairie dog (Cynomys gunnisoni), the economic rodents, the unidentifiable small mammal remains, carnivores, mule deer (Odocoileus hemionus), pronghorn (Antilocapra americana), mountain sheep (Ovis canadensis), the unidentifiable large mammal remains, turkey (Meleagris gallopavo), bird (Aves), and the unidentifiable bird remains; and the total number of elements in the sample. Appendix 2 gives the raw data for the assemblages.

Discriminant analysis (SPSS program Discriminant) was used to delineate the differences in these assemblages. It operates through the derivation of a set of discriminant functions that maximize between group differences relative to within group differences. The functions are made up of weighted, discriminating variables and they are hierarchically arranged. The first function accounts for as much of the between group variance as possible, the second for as much as possible of that not accounted for by the first and so on (Droessler 1981). In this instance the variables (percentages of each taxon) are used to define functions that describe the temporal differences in the data set as a whole. Taxa that remain more or less constant in use or are infrequently found are ignored in favor of those that vary with the temporal assignments. The temporal groups are then weighed in terms of the functions defined. A description of how each group (in this case temporal groupings) relates to the defined function is then possible.

This particular multivariate technique has the advantage of being able to deal with many variables and populations simultaneously, and it takes into consideration the effects of intercorrelations and what is contributing to the differences (Droessler 1981). It is particularly appropriate for data concerned with subsistence systems where changes may be patterned. The 'Direct Option' was used because it allows for the inclusion of all independent variables in the analysis (Nie and others 1975).

Results

The analysis was initially used on two different data sets. The first consisted of the three common small mammals (cottontail rabbit, jack rabbit, and prairie dog), and the economic rodents. The economic rodents include squirrels and other rodents that were large enough to have served as food items and that often exhibit evidence of processing (i.e., burning). The second data set was comprised of all of the taxa coded.

The first analysis was designed to monitor changes in the local small mammal procurement throughout the occupation of the canyon and the second for overall patterning. Tables 3 and 4 give the discriminant coefficients and how they relate to the time groupings. Figures 1 and 2 give the scatter plots. The temporal groupings are a combination of the traditional chronological assignments and ceramic associations, or the predominant ceramic type, for the deposit. Late Mix refers to deposits characterized predominantly by Chaco-McElmo wares. In analyzing Pueblo Alto, I found that within the Late Mix deposits (as defined by Windes, personal communication) some were demonstrably different in faunal content. I believe these differences are temporal and that the "Late-Late Mix" deposits represent some of the latest deposition at Pueblo Alto. These are far more similar to the Late Pueblo III assemblages found at 29SJ633 than to any others at Pueblo Alto (Akins 1982a).

When only the small mammals were considered, the first function was defined almost entirely by cottontail rabbit and can be used to monitor the utilization of this taxon. Its use or importance was greatest early in the time framework and decreased steadily until Late Pueblo III when it rose. In conjunction with this, the prairie dog and economic rodent combination (Function 2) appears to have been of little importance except in the Early-Late Mix cases. The fact that jack rabbits do not enter into the functions may suggest that this species played a relatively stable role in small mammal procurement with more fluctuation occurring in the other three taxa. The percentage of the assemblages correctly classified using these functions was fairly low and may suggest that the patterns are not that distinct or that the differences are not very important.

Table 3. Summary of discriminant function factor coefficients.

Small Mammals Only:	Function 1	Function 2	Function 3
	.81 cottontail	.75 ec. rodent	.73 pr. dog
		.66 pr. dog	-.60 ec. rodent
variance explained:	58.7%	24.1%	10.3%

% correctly classified: 41.5

All taxa:	1.03 turkey	.81 cottontail	.89 unid. bird
		.79 small mam.	
		.63 jack rabbit	
variance explained:	70.4%	15.1%	6.9%

% correctly classified: 69.1

Table 4. Temporal groupings and discriminant function coefficients.

Temporal Group	Function 1	Function 2	Function 3	No. of Cases	% Correctly Classified
Small Mammals:					
Basketmaker III	1.18	-0.07	0.35	16	50.0
Early Red Mesa	2.28	2.04	-0.85	2	50.0
Late Red Mesa	0.04	-0.25	-0.12	21	0.0
Gallup	-0.14	-0.30	-0.04	31	74.2
Early-Late Mix	-0.91	0.79	0.35	14	42.9
Late-Late Mix	-1.22	-0.21	-0.13	5	0.0
Late Pueblo III	-0.20	0.26	-0.84	5	20.0
All taxa:					
Basketmaker III	-0.84	1.66	0.24	16	68.8
Early Red Mesa	0.64	2.19	-0.06	2	50.0
Late Red Mesa	-0.89	0.38	0.48	21	42.9
Gallup	-1.06	-0.90	-0.24	31	87.1
Early-Late Mix	-0.04	-0.84	-0.39	14	57.1
Late-Late Mix	6.99	-1.05	1.84	5	80.0
Late Pueblo III	5.90	1.14	-2.03	5	100.0

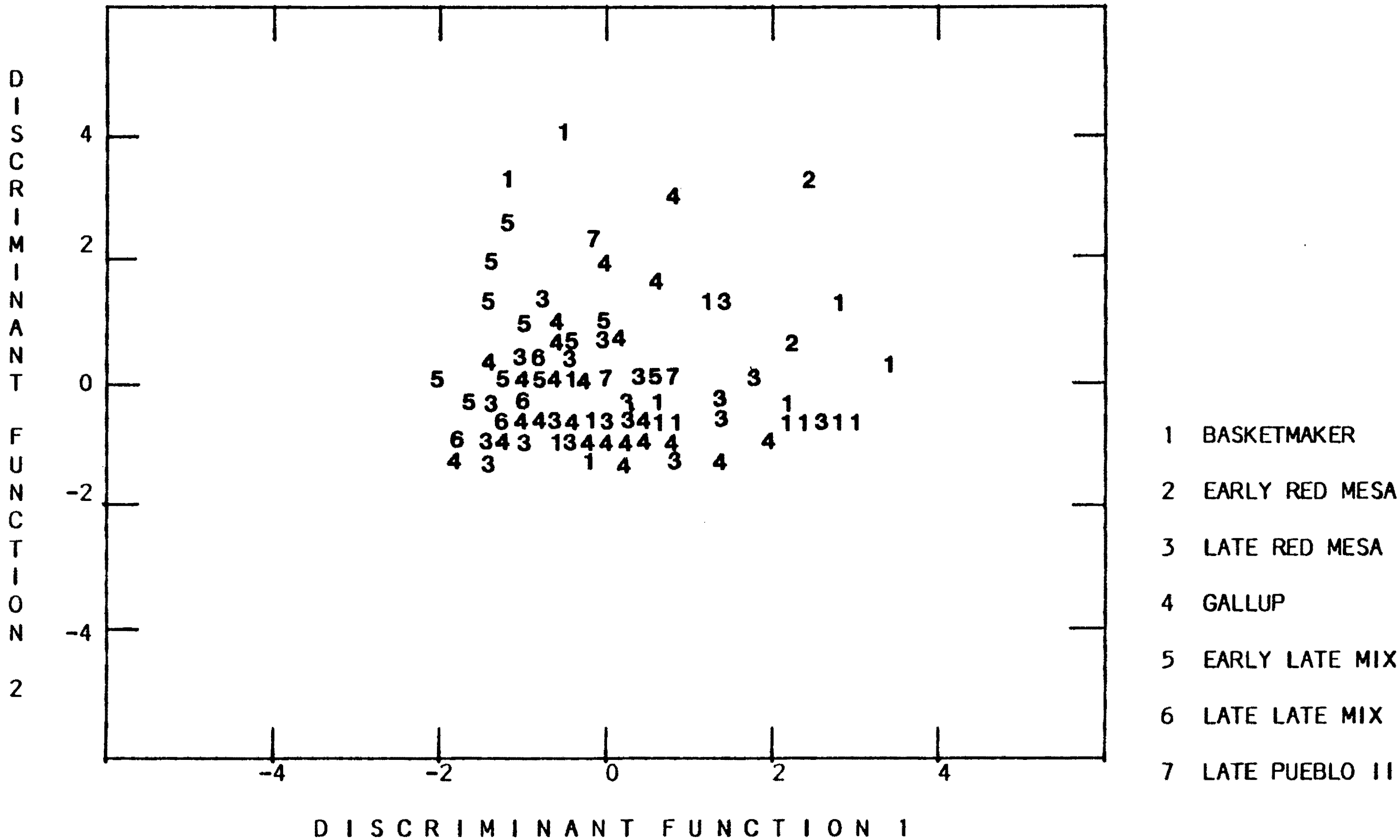

Figure 1. Scatterplot for the small economic mammals.

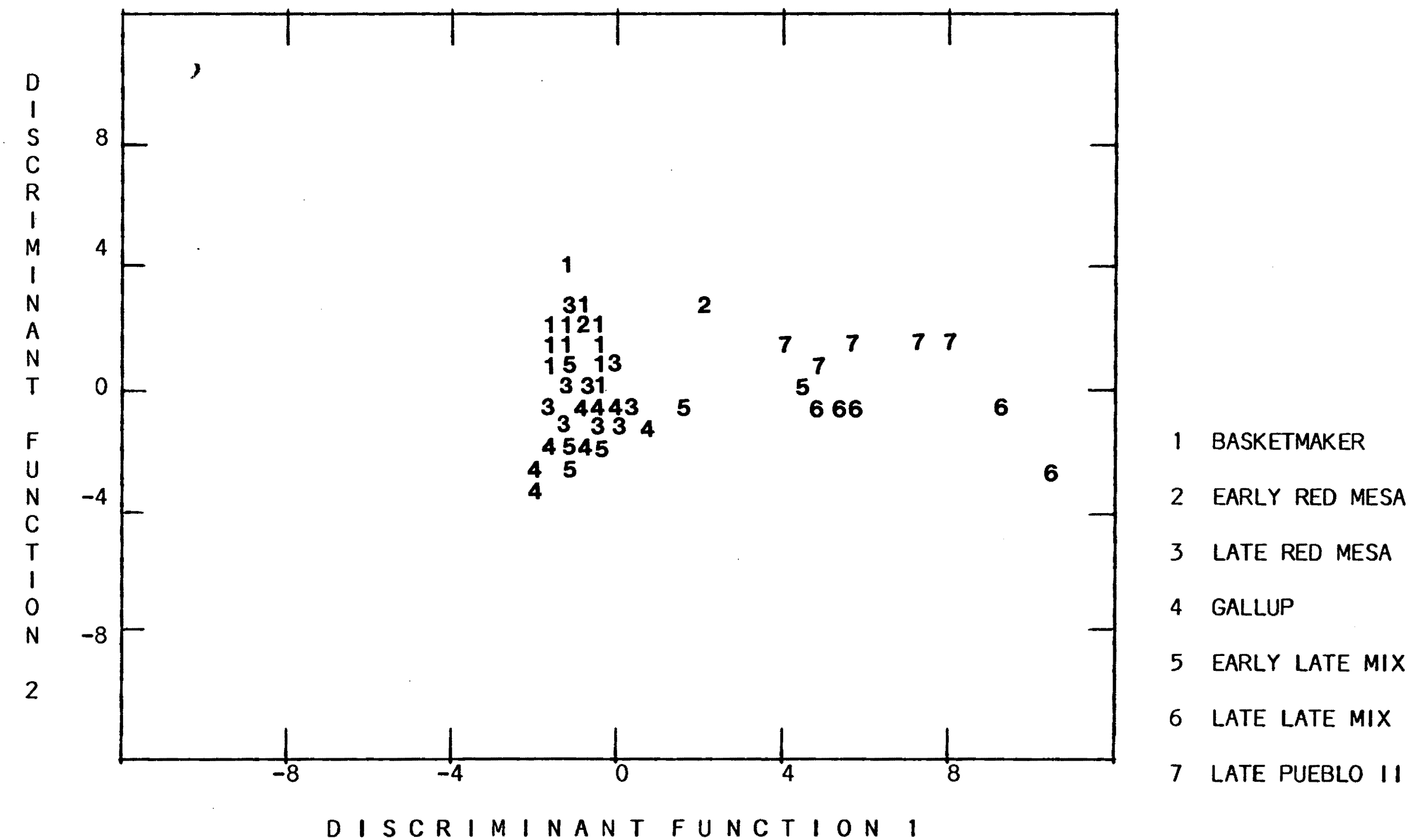

Figure 2. Scatterplot for all 13 taxa.

When all 13 taxa are considered (Tables 3 and 4 and Figure 1) Function 1 is defined almost entirely by turkey. Elements from turkeys are quite rare until late in the Anasazi occupation of the canyon (Late-Late Mix and Late Pueblo III). The second function is composed of both rabbit species and the unidentified small mammal group, which largely consists of rabbit elements that were too fragmentary for positive identification. The third function is defined by the unidentified bird group but it accounts for very little of the explained variation.

To summarize, turkey became very important late in the sequence--mostly at the expense of the small mammals. The discriminant coefficients (Table 4) and Figure 2 suggest that the Early-Late Mix and Late-Late Mix divisions at Pueblo Alto are justified. The difference between these two is so great that none of the cases in these two groups were classified by the discriminant function with the other.

In order to define the differences between the sites within each temporal grouping, the time periods represented by the larger number of assemblages were examined. These included the Basketmaker, the Late Red Mesa, the Gallup, and the Early-Late Mix temporal groupings. All taxa were used in the analyses and the groups being discriminated were the sites. Table 5 presents the functions and discriminant coefficients. The analysis of each of the temporal groups resulted in 100% of the cases correctly classified. This suggests that while there are overall temporal trends in the faunal assemblages, the sites have distinctive patterns.

The functions defined in these analyses are complex and often difficult to explain. In the Basketmaker sites the difference is probably due to environmental setting. Site 29SJ628 is located in an area that had more access to the open shrub and grassland habitat preferred by jack rabbits than did 29SJ423. For the Late Red Mesa assemblages, 29SJ1360 stands out as having much more pronghorn than any other sites at that time. This, too, may be due to the site location relative to access to the south. The Pueblo Alto assemblages appear to be the more unusual of those from the Gallup analysis, mainly because it had few economic rodent and turkey remains. In the final time grouping, Early-Late Mix, it is 29SJ633 that stands out for its lack of all of the taxa contributing to the function.

While there are definite differences in the sites, these are not as important as the overall temporal trends. The taxa contributing to the functions make up very small percentages of the assemblages and occur in combinations that cannot be explained logically.

Discussion

The temporal analysis suggests that the taxa most sensitive to temporal changes are turkey and the two rabbit species. Of the small mammals, the cottontail appears to be the most significant. Identifiable elements from the artiodactyls occur in very low frequencies, but the species contribute a large percentage of the estimated meat available at a site (Akins 1981a-f, 1982a and b). Comparison of the estimated amount of meat consumed at these sites suggests that pronghorn was the more utilized species until Late Red Mesa/Gallup times when a reversal occurred and deer became the predominantly used artiodactyl (Akins 1982c). Although the discriminant analysis does not recognize the significance of these large mammals, because they are so few in number, they cannot be ignored.

Figure 3 summarizes the temporal trends using the assemblage means for each temporal group. Prairie dog and the cumulative total of the artiodactyl and the unknown large mammals have also been added to the taxa identifed by the discriminant analysis as significant. Early Red Mesa was deleted because it was represented by only two assemblages. The graph shows a steady decline in the proportions of cottontail and jack rabbits--except for the sharp increase in cottontail in the Late Pueblo III cases. The decline of these two may have been due to overexploitation. It appears as though these once heavily relied on species became sufficiently sparse or unreliable that a new source of animal resources was sought out--the artiodactyls. Alternatively, the increase in the availability of artiodactyl resources may have been the result of expanded social networks and would have relieved the pressure on the rabbits. However, since the rabbits continue to fall after artiodactyls also start to decline, this is not as likely as the first suggestion.

Table 5. Discriminant coefficients for sites by time grouping.

Site	Function 1	Function 2	No. of Cases
Basketmaker III:			
	2.51 jack rabbit		
	1.83 economic rodent		
	1.17 unidentified bird		
variance explained	100.0%		
29SJ423	-10.51		5
29SJ628	3.50		7
Late Red Mesa:			
	1.65 pronghorn	1.98 prairie dog	
	-1.34 mt. sheep	1.08 bird species	
	-1.01 jack rabbit	1.08 unid. bird	
		-1.06 cottontail	
variance explained	80.94%	10.27%	
Pueblo Alto	-4.28	1.23	6
Una Vida	-5.24	1.46	1
29SJ629	-1.62	6.06	2
29SJ627	-0.91	-2.27	10
29SJ1360	21.64	.88	2
Gallup:			
	1.57 ec. rodent	0.87 pronghorn	
	1.14 turkey	-0.64 ec. rodent	
		-0.61 deer	
variance explained	88.18%	11.82%	
Pueblo Alto	-1.75	0.18	25
Una Vida	5.00	-3.74	3
29SJ627	9.62	2.22	3
Early-Late Mix:			
	15.26 jack rabbit	2.11 jack rabbit	
	13.10 bird species	2.02 ec. rodents	
	10.87 unid. bird	1.68 prairie dog	
	10.26 prairie dog		
variance explained	98.49%	1.51%	
Pueblo Alto	9.36	1.27	9
29SJ633	-45.14	0.90	2
29SJ627	2.00	-4.42	3

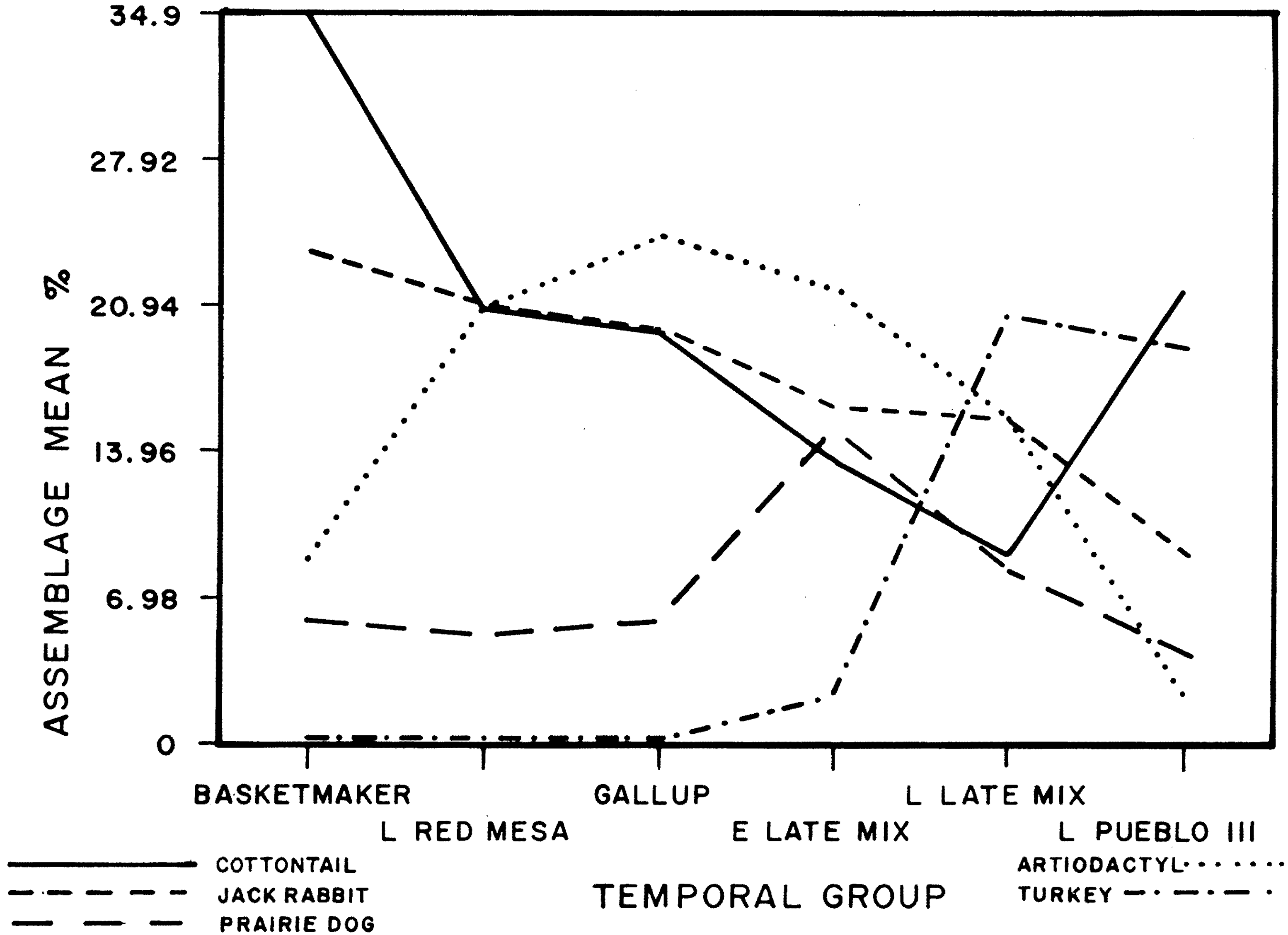

Figure 3. Percentages of selected taxa through time.

The increase in utilization of the artiodactyls shows up not only in the number of elements but also the MNIs and the amount of meat represented at a site. I have previously suggested (Akins 1982c) that much of the artiodactyl utilized by the Chacoans was imported. There were simply inadequate numbers to have supported the population. If local artiodactyls had provided all of the meat eaten in the canyon, a population of 250 could have been fed without going beyond the species ability to recover. As many as 700 persons could have been supported using all of the locally available fauna. These figures are based on the number of animals the area could have supported. The locally available fauna could not have sustained a growing human population. Most of the artiodactyl resources were more likely imported through trade relations or procured by the Chacoans elsewhere in the basin.

The peak in artiodactyl use corresponds nicely with ceramic and lithic evidence (Toll and Cameron this volume) for increases in exchange as evidenced by nonlocal products. It is interesting that the replacement of pronghorn by deer as the primary food item corresponds in time to Toll's change from large amounts of southern tempering materials to those from the Chuskas. Deer availability appears to correspond with the availability of Washington Pass chert. Range maps (Findley and others 1975) for the two species suggest that the south and southeast were good pronghorn habitat and the Chuska Mountains were good for deer. Both species could have been found north of the canyon.

After Gallup times there was a relative decline in the artiodactyls with a sharp rise in prairie dog and a slight increase for turkey. It is tempting to suggest that a decrease in artiodactyl availability (which could be the result of overexploitation or deteriorating social relations) caused the population to look for an alternate meat source. Prairie dog seems to have accomplished this temporarily.

In the final two periods the percentages of turkey rose dramatically while all other taxa continued to decline--except for the rise in cottontails during Late Pueblo III. Perhaps this suggests recovery of this species due to a decrease in the human population. This increase in use of the turkey corresponds with Toll's observation (this volume) that the tempering materials were now coming from the north where turkey had been a recognized food item. I have suggested (Akins 1982a) that, on the basis of a relative lack of immature birds in the late periods at Pueblo Alto, turkeys were brought in as mature birds intended for consumption.

It should come as no surprise that the faunal remains correspond to other aspects of the archaeological record. When modeling the system and testing these models we must also consider that food resources were moved, possibly in great quantities. Like the ceramics and lithics (this volume) there is evidence for far greater quantities of faunal resources at the great house site of Pueblo Alto than at the villages. Based on the faunal remains recovered from testing the trash mound at Pueblo Alto, I have estimated that the mound alone contained over 1.75 million bones. The relative density compared to sherds is also far greater. In the village sites this ranged from 9 to 11 sherds per bone at 29SJ629 (n=2) and from 4 to 11 sherds per bone at 29SJ627 (n=2). In the Pueblo Alto trash mound bone outnumbered sherds, resulting in a ratio of .8 sherds per bone (Akins 1982a).

Even with these densities the number of persons who could have been fed by the meat represented in the trash mound at Pueblo Alto is not high. The estimated meat available (all that could possibly be represented assuming an entire animal for each MNI) and the estimated meat consumed (where only the body parts representing the artiodactyls are considered to have been consumed) were converted to "man years." This was based on a daily intake of 200 calories of meat, which is equivalent to approximately 40% of a cottontail rabbit. Assuming that the mound took approximately 70 years to accumulate (T. Windes, personal communication), the estimated meat consumed could have resulted from a human population of 26, and that available could have resulted from 91 persons. This does not suggest a large resident population or large influxes of persons to the site.

Furthermore, the layers in the trash mound do not exhibit the characteristics of communal cooking that would been expected (a narrow range of species and cooking patterns suggestive of communal processing) if the accumulations were the result of ritual gatherings of large numbers of persons. Examination on a layer by layer basis does not suggest that habitation was seasonal. The deposits show much variability in those taxa that are seasonal in their availability (hibernators) as well as in the numbers of very immature individuals (Akins 1982a).

In conclusion, the subsistence strategies employed by the Chacoans may have been more than an adaptation to changing availability in the local resources. Shifting alliances with nearby populations played a major role. The changes in strategy are evident in both the great house and village sites; the observed differences are in the quantity of the remains rather than in the content.

Appendix 1

Faunal Assemblages

Observation		Provenience		Sample Size
1	Pueblo Alto	Trash Mound	Layer 10	92
2			Layer 11	744
3			Layer 18	320
4			Layer 22	262
5			Layer 35	794
6			Layer 37	87
7			Layer 43	340
8			Layer 44	147
9			Layer 45	346
10			Layer 55	310
11			Layer 56	260
12			Layer 58	191
13			Layer 62	280
14			Layer 69	161
15			Layer 81	240
16			Layer 104	223
17			Layer 113	253
18			Layers 1-4,8	305
19		East Plaza	Unit 1, Surface 1	194
20			Unit 2, Surface 1	259
21		Other Structure 6		243
22		Kiva 16		237
23		Room 103	Floor 1, floor fill	938
24			Floor 2, floor fill	140
25			Floor 4, floor fill	515
26		Room 110	Floor 1, floor fill	1023
27			Floor 1, replasters 7-9	483
28		Room 112	Surface 1, floor fill	721
29			Floor 1, floor fill	342
30			Floor 2, floor fill	549
31			Floor 3, floor fill	137
32			Floor 4, floor fill	322
33		Kiva 15	floor fill	332
34		Kiva 13		519
35		Room 142	roof fall	375
36		Room 143	Floor 1, floor fill	134
37		Room 146	roof fall	95
38		Room 147	Floor 1 associations	332
39		Kiva 10	Levels 15-18	1806
40			Levels 19-23	736
41			Levels 24-27	146
42			Level 28	92
43		Room 146	Floor 3, floor fill	173
44		Plaza Grid 8	Surface 8 association	219
45		Plaza Grid 8	Surface 9 association	1156

Appendix 1 (continued)

Observation		Provenience		Sample Size
46	Una Vida	Room 21	Floor 2 association	129
47		Room 23	subfloor vent	2488
48		Room 83	Floor 2	112
49		Room 84	drain	146
50	29SJ633	Room 7	Layer 2	140
51			Layer 3	492
52			Layer 4 and rock concentration	523
53			Layers 5 and 6	701
54			Floor 2 association	136
55		Room 8	Fill above Floor 1	82
56			Floor 2 association	144
57	29SJ629	Pithouse 3 lower fill		259
58		Other Pit 14		157
59	29SJ423	FS# 66	East Rubble Mound, Level 1	526
60		FS# 71	Pithouse A fill	271
61		FS# 336	Pithouse B - Area I	331
62		FS# 289	Pithouse B - Feature 2	253
63	29SJ627	Room 10	Floor 2	140
64		Pithouse C	Layer 3	440
65			Layer 4	339
66			Layer 5	92
67			Layer 6	127
68			Layer 7	148
69			Layer 9	306
70			Floor 1	76
71		Kiva D	Levels 1 and 2	156
72			Levels 3 to 6	220
73			Levels 7 to 10	112
74		Kiva E	Layer 3	833
75			Layer 4	209
76			Layer 5	106
77		Kiva F	Layer 5	142
78			Layer 6	208
79	29SJ628	Pithouse C	Layer 1	113
80			Layer 2	731
81			Layer 3	1607
82			floor and features	151
83		Pithouse D	Layer 1	72
84			Layer 2	140
85		Pithouse A	Level 3	141
86			Level 4	87
87		Pithouse E	Levels 1 and 2	136
88			Levels 4 and 5	157
89		Pithouse C antechamber	Levels 2 and 3	509
90		Pithouse D antechamber	trash fill	75
91	29SJ1360	Kiva A	Level 1	206
92			Levels 2 and 3	114
93	29SJ724	Pithouse A	Floor 1 association	175
94	29SJ299	Pithouse E	Floor 2	81

Appendix 2

Data Matrix Used in Discriminant Analysis

Site	Time	a	b	c	d	e	f	g	h	i	j	k	l	m	n=	obs
							% of Taxa									
Pueblo Alto	Gallup	08	17	14	01	26	00	02	00	00	29	00	00	00	0092	01
	"	08	00	00	00	69	00	01	00	00	20	00	00	00	0744	02
	"	09	19	02	01	58	00	01	00	00	11	00	00	00	0320	03
	"	49	00	05	00	17	00	03	00	00	19	00	00	00	0262	04
	"	25	10	08	00	19	00	03	01	00	25	04	00	00	0794	05
	"	29	18	01	00	29	00	03	01	01	15	00	00	00	0087	06
	"	20	28	05	00	23	00	00	00	00	19	00	00	01	0340	07
	"	22	25	01	00	15	00	17	01	01	20	00	01	00	0147	08
	"	46	26	01	00	19	00	01	00	00	07	00	00	00	0346	09
	"	41	21	00	00	29	00	02	00	00	07	00	00	00	0310	10
	"	13	32	01	00	19	00	01	00	00	31	00	00	01	0260	11
	"	11	24	15	00	16	00	06	00	00	26	01	00	00	0191	12
	"	14	19	08	01	32	00	03	01	00	22	00	00	00	0280	13
	"	11	15	02	01	10	00	03	00	01	31	00	01	00	0161	14
	"	16	05	02	00	08	00	04	01	01	47	00	00	00	0240	15
	"	27	14	08	00	21	00	04	00	00	23	00	01	00	0223	16
	"	22	15	04	00	30	00	02	00	00	20	00	00	01	0253	17
	L.R.M.	16	06	09	01	46	00	01	00	03	44	00	00	00	0305	18
	L.L.M.	10	20	10	00	22	00	00	00	00	09	16	00	05	0194	19
	L.L.M.	14	14	16	01	19	00	00	00	01	07	11	00	09	0259	20
	E.L.M.	15	14	33	01	16	00	03	01	00	06	05	00	02	0243	21
	E.L.M.	11	12	08	01	18	00	02	00	02	36	01	01	03	0237	22
	E.L.M.	19	05	16	02	23	00	01	00	00	07	15	00	00	0938	23
	Gallup	18	08	06	00	28	00	03	00	00	17	01	00	02	0140	24
	Gallup	23	21	04	00	25	00	01	00	00	60	00	00	00	0515	25
	Gallup	19	21	07	01	24	00	02	00	00	06	00	01	00	1023	26
	Gallup	28	09	02	00	17	00	05	01	01	15	00	01	01	0483	27
	E.L.M.	21	22	28	00	10	00	02	00	00	08	00	00	00	0721	28
	Gallup	18	30	26	00	10	00	01	00	00	06	00	00	00	0342	29
	Gallup	13	32	20	00	11	01	00	00	00	02	02	00	00	0549	30
	E.R.M.	33	38	12	00	06	00	01	01	00	04	01	00	01	0137	31
	E.R.M.	28	30	16	00	08	01	00	00	00	12	00	00	00	0322	32
	E.L.M.	08	36	11	01	22	00	04	00	00	09	03	00	00	0332	33
	Gallup	13	24	03	00	23	00	03	00	00	29	00	00	01	0519	34
	L.L.M.	05	08	04	00	02	00	00	00	00	17	30	00	09	0375	35
	E.L.M.	06	23	13	02	23	00	00	01	01	27	01	01	01	0134	36
	L.L.M.	11	13	06	02	10	00	05	00	01	13	29	00	02	0095	37
	L.L.M.	05	23	06	00	16	00	02	03	01	19	17	01	03	0332	38
	E.L.M.	09	19	26	01	23	00	01	00	00	14	02	00	02	1806	39
	E.L.M.	15	32	16	02	17	01	01	01	00	14	00	00	00	0736	40
	E.L.M.	13	06	24	04	11	00	10	00	00	30	00	01	00	0146	41
	Gallup	29	09	11	01	07	00	02	00	00	33	00	05	00	0092	42
	E.R.M.	25	32	00	00	21	00	00	00	00	06	00	11	01	0173	43
	E.R.M.	20	17	03	00	51	00	00	00	00	03	00	02	02	0219	44
	E.R.M.	16	12	02	01	39	00	00	00	00	26	00	01	01	1156	45
Una Vida	Gallup	21	08	12	05	20	01	01	00	01	08	00	00	00	0129	46
	E.R.M.	19	14	08	02	20	01	00	00	01	14	00	00	01	2488	47
29SJ633	Gallup	14	22	04	08	09	00	01	00	00	09	00	00	00	0112	48
	Gallup	11	38	12	02	14	01	09	00	00	11	00	01	01	0146	49
	L.P. III	35	12	05	02	25	01	00	00	00	04	14	01	00	0140	50
	L.P. III	13	03	04	01	57	00	00	00	00	01	15	00	00	0492	51
	L.P. III	21	15	04	02	29	00	00	00	00	00	23	00	00	0523	52
	L.P. III	24	10	02	01	32	00	00	00	00	00	26	00	00	0701	53
	E.L.M.	20	01	02	04	20	00	00	00	01	02	01	08	00	0136	54
	L.P. III	16	06	07	06	29	00	00	00	00	07	17	01	01	0082	55
	E.L.M.	35	07	03	02	32	01	00	00	00	01	01	02	00	0144	56
29SJ629	E.R.M.	06	24	12	01	11	01	02	01	01	14	01	01	05	0259	57
	E.R.M.	14	17	20	02	13	02	02	00	00	12	00	00	00	0157	58
29SJ423	BM	30	04	00	00	58	00	00	00	00	06	00	00	00	0526	59
	BM	24	04	02	00	56	02	00	00	01	03	00	01	00	0271	60
	BM	35	07	00	01	41	02	00	01	01	09	00	00	00	0331	61
	BM	27	02	00	01	49	00	00	00	00	03	00	00	00	0253	62

Appendix 2 (continued)

Site	Time	a	b	c	d	e	f	g	h	i	j	k	l	m	n=	obs
							% of Taxa									
29SJ627	E.R.M.	26	06	06	03	29	01	01	00	00	19	00	01	00	0140	63
	E.R.M.	02	22	01	00	34	01	01	01	01	33	00	00	00	0440	64
	E.R.M.	05	16	00	00	28	00	01	02	01	42	00	00	01	0339	65
	E.R.M.	08	35	00	01	35	00	02	01	00	17	00	00	00	0092	66
	E.R.M.	57	19	03	01	05	06	00	00	00	05	00	01	00	0127	67
	E.R.M.	40	24	05	00	08	08	01	01	00	07	00	00	00	0148	68
	E.R.M.	40	26	04	02	11	02	01	00	00	12	01	00	01	0306	69
	E.R.M.	26	28	03	05	17	01	00	03	00	10	00	00	00	0076	70
	Gallup	15	22	01	06	12	01	06	02	01	27	00	00	02	0156	71
	Gallup	09	41	00	00	09	00	04	01	00	23	06	00	03	0220	72
	Gallup	08	47	00	01	03	02	08	01	04	18	02	00	02	0112	73
	E.L.M.	03	12	15	00	11	01	04	01	04	30	01	00	02	0833	74
	E.L.M.	09	12	11	00	06	03	03	00	00	50	02	00	00	0209	75
	E.L.M.	06	26	07	01	28	00	05	00	00	22	03	00	00	0106	76
	E.R.M.	21	22	01	01	32	02	02	01	00	11	01	00	03	0142	77
	E.R.M.	28	15	05	01	11	01	02	01	01	04	00	00	00	0208	78
29SJ628	BM	37	40	03	01	03	02	00	00	00	14	00	00	00	0113	79
	BM	38	40	02	01	03	02	00	01	00	08	00	01	00	0731	80
	BM	45	42	02	01	03	01	00	00	00	04	00	00	00	1607	81
	BM	55	32	03	03	03	00	00	01	00	01	00	01	00	0151	82
	BM	10	37	15	00	10	03	00	03	00	21	00	01	00	0072	83
	BM	58	25	02	01	01	01	00	01	03	05	00	03	00	0140	84
	BM	48	23	03	05	11	00	00	01	00	03	00	01	00	0141	85
	BM	21	21	47	01	03	01	01	00	01	03	00	00	00	0087	86
	BM	19	37	01	01	02	08	01	04	00	09	06	02	04	0136	87
	BM	26	26	06	01	08	07	01	02	00	18	00	01	00	0157	88
	BM	48	27	01	01	02	00	00	00	00	01	00	17	01	0509	89
	BM	37	12	09	04	09	13	01	01	00	10	01	00	00	0075	90
29SJ1360	L.R.M.	00	15	00	02	03	04	04	09	00	50	03	00	06	0206	91
	L.R.M.	06	25	02	00	04	08	04	14	03	25	02	01	02	0114	92
29SJ724	E.R.M.	37	34	05	03	17	01	00	00	00	01	00	01	01	0175	93
29SJ299	E.R.M.	31	36	11	08	01	01	00	00	00	00	07	00	01	0081	94

Codes

Time groupings

BM	Basketmaker
E.R.M.	Early Red Mesa
L.R.M.	Late Red Mesa
E.L.M.	Early Late Mix
L.L.M.	Late Late Mix
L.P. III	Late Pueblo III

% of taxa

a	% of *Sylvilagus* sp. (cottontail rabbit)
b	% of *Lepus californicus* (jack rabbit)
c	% of *Cynomys gunnisoni* (prairie dog)
d	% of economic rodents (squirrels, economic rodents)
e	% of unidentified small mammal
f	% of carnivores
g	% of *Odocoileus hemionus* (mule deer)
h	% of *Antilocapra americana* (pronghorn)
i	% of *Ovis canadensis* (mountain sheep)
j	% of unidentified large mammal
k	% of *Meleagris gallopavo* (turkey)
l	% of wild bird species
m	% of unidentified bird

n =	number of elements in sample
obs	control number

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TAXONOMIC DIVERSITY IN FLOTATION AND MACROBOTANICAL ASSEMBLAGES FROM CHACO CANYON

Mollie S. Toll

Abstract

Flotation and macrobotanical analyses have been undertaken on remains from archaeological sites excavated by the Division of Cultural Research, Chaco Center, National Park Service. The objective is to provide documentation of prehistoric utilization of cultivated and wild plant taxa. This study considers differences in the taxonomic diversity of plant assemblages from two distinct site types in Chaco Canyon--small villages and the larger planned towns. In assessing the significance of differences between collections, discussion is directed to methodological, taphonomic, and archaeological factors that influence the observed variability.

Introduction

Flotation and macrobotanical analyses have been undertaken on remains from village and town sites that were part of the Chacoan system during Pueblo I through Pueblo III times. The overall objective of the analyses is to provide documentation of prehistoric utilization of cultivated and wild plant taxa and to examine variability and change in that utilization. In this paper one aspect of the data, taxonomic diversity, is examined in some detail with the objective of evaluating some of the interplay between archaeological and methodological variables.

Diversity is used here in its simplest sense, the variety of species present, measured as number of plant taxa found at a site or in a certain provenience category within a site (such as firepits or storage rooms). Because of the nature of flotation data, diversity measured as the number of species present in combination with the relative proportion of each member species is a more difficult tool to apply. Flotation assemblages are characteristically and consistently low in diversity in this sense, with a few taxa (usually weedy annuals) accounting for the vast majority of seeds recovered and a large number of other taxa making up the remainder. There is commonly a great deal of variability from one sample to the next. For instance, at a site where 25 taxa may be represented, most sample locations will have from 5 to 10 taxa present, with a range of perhaps 2 to 18. The configuration of pollen data is quite different, and might lend itself more readily to diversity analyses incorporating concepts of richness and evenness, as measured by the Shannon-Weiner diversity index (Pielou 1974).

The village sites that will be discussed here (29SJ627 and 29SJ629) each consist of approximately 20 rooms added by accretion, while Pueblo Alto is a large, planned structure exhibiting considerably more sophisticated construction techniques. While the principal conclusions are based on comparison of the three sites, flotation data from other Chaco village sites are included at certain junctures in order to broaden the comparative base.

The patterning of botanical data might reasonably be expected to relate to the obvious differentiation of small and large site types in Chaco Canyon. Given the economic, social, and organizational differences that have been postulated (Vivian 1970), dissimilar subsistence strategies could be expected. In addition, if towns indeed functioned as regional centers of exchange (H.W. Toll 1981), then botanical remains may reflect greater access to nonlocal resources. Accordingly, taxonomic diversity is expected to vary nonrandomly with respect to site type.

At first glance, however, flotation and macrobotanical data do not appear to follow such a pattern. Site 627 stands out as having a low average density of seeds per sample and a narrower range of taxa represented (Table 1). In particular, nonweedy economic taxa are almost entirely missing at this site (Table 2). Several explanations of this pattern present themselves. Low average and overall seed density at 627 may be re-

Table 1. Density of seeds and diversity of taxa in flotation samples.

		DENSITY[1]		DIVERSITY	
	no. of samples	$\bar{x}$ no. of seeds per sample	total no. of seeds	$\bar{x}$ no. of taxa per sample	total no. of taxa
29SJ627[2]	75	71.4	5,351.6	5.6	25
29SJ629[3]	74	685.3	50,709.7	9.9	30
Pueblo Alto[4]	124	88.8	11,006.2	6.3	33

[1]Based on estimated number of seeds (standardized to one-liter sample size).

[2]Struever 1977. [3]M. Toll 1981. [4]Toll in preparation.

Table 2. Chaco sites' flotation assemblage composition (all specimens/charred occurrences only).

USEFUL WEEDS

site	$\bar{x}$ no. taxa per sample	total no. taxa	% samples containing *Chenopodium*
29SJ627	2.8/0.6	11/7	53/16
29SJ29	5.1/0.9	12/10	92/19
Pueblo Alto	3.3/0.8	13/12	68/16

Taxa included: *Amaranthus*, *Cleome*, *Chenopodium*, *Corispermum*, *Cycloloma*, *Helianthus*, *Descurainia*, *Mentzelia*, *Sphaeralcea*, *Portulaca*, *Nicotiana*, *Physalis*, *Solanum*.

NON-WEEDY ECONOMICS

site	$\bar{x}$ no. taxa per sample	total no. taxa	%samples containing *Pinus edulis*
29SJ627	0.2/0.1	6/3	0/0
29SJ629	0.8/0.4	8/6	5/1
Pueblo Alto	1.3/0.7	10/9	35/10

Taxa included: *Juniperus*, *Pinus edulis*, *Scirpus*, *Oryzopsis*, *Sporobolus*, *Yucca*, *Rhus*, *Echinocereus*, *Opuntia*, *Atriplex*.

CULTIVARS

site	$\bar{x}$ no. taxa per sample	total no. taxa	% samples containing *Zea*
29SJ627	0.2/0.2	1/1	21/21
29SJ629	0.6/0.6	2/2	54/54
Pueblo Alto	0.6/0.6	3/3	53/53

Taxa included: *Zea*, *Phaseolus*, *Cucurbita*.

sponsible for underrepresentation of low frequency taxa, thus masking true differences between town and village sites. On the other hand, the three sites may represent highly similar subsistence activities and subsistence debris, with the apparent variability attributable to methodological or taphonomic factors. A third, obscure, possibility is that the second village site, 629, may have had greater interaction with town sites (for instance as indicated by abundant evidence of turquoise artifact manufacturing; Windes 1978). This last possibility was considered unlikely, as no other artifact categories at Site 629 show any such affinity with Pueblo Alto. The task of this paper is thus considered to be distinguishing real differences in taxonomic diversity at these sites from apparent differences affected by sample size and other factors, and interpreting the significance of variability or lack of variability.

Methods And Data Collection

Flotation samples used in this study were collected as one liter soil samples from specified site locations during excavations. All were processed according to a modification of the method developed at Salmon Ruin (Bohrer and Adams 1977). This involves pouring the sample solution through a very fine screen rather than scooping floating and suspended materials out of the water. No aids to dispersion such as frothing or chemical additives were used. Such a simple procedure is possible because Chaco area soils consist largely of sand.

Flotation analysis at Site 627 was experimental in several respects, with the result being that samples were selected for analysis very differently than at the other sites. Some of these differences appear to have some significant bearing on the flotation results in general, and specifically on the taxonomic diversity observed. At Site 627 certain locations were chosen for more detailed investigation (Cully 1977; Struever 1977) in an effort to pinpoint the degree of variability within a provenience type and hence provide some guidelines for pollen and flotation sampling regimes at other Chaco sites. In this vein, analysis included eight samples taken in a checkerboard grid pattern from the floor contact level in a storage room at 627 and another eight samples from floor plaster in the same room. In another room, flotation samples were taken from a series of eight postholes. The net result was several sizable blocks of unproductive samples (including floor plaster, floor fill, and postholes) that were low in pollen counts as well as larger botanical debris. Further, several features chosen for analysis from a computer inventory later proved to have been cleaned out prehistorically and were filled with alluvium.

Based on what was learned at Site 627, Site 629 and Pueblo Alto were sampled considerably more effectively. Primary deposition became an essential criterion for inclusion of feature sample locations. In several cases at 629, pinch samples were taken from the floor level throughout part of a room in order to encompass some of the variability present without expending a large number of samples on a small number of floors. Although about 75 samples were analyzed from each of the two village sites, the spread of sample locations is very different. Clumps of samples were taken at Site 627, whereas at Site 629 samples within any given provenience type were taken from rooms throughout the pueblo. The samples from Pueblo Alto were collected as at Site 629. At Pueblo Alto a scanning technique (requiring a considerably smaller investment of microscope time per sample) was used to review alternate grids of all occupation surfaces in rooms, and samples from a representative selection of features in each excavated room were completely sorted.

Discussion Of Results

Flotation assemblages at these Chacoan sites were grossly similar in that most seeds belonged to weedy plant species growing in the immediate vicinity of the sites (principally goosefoot, purslane, tansymustard, and stickleaf). These annual weeds produce tremendous numbers of tiny seeds and have extensive records of economic use in the ethnographic literature, both as tender greens early in the season and as seed crops later on. Taxa with less promiscuous natural seed dispersal patterns, as beeweed, groundcherry, wild tobacco, and cacti, are distributed far more sparsely in these sites. This second category of economic taxa seems to have a wider distribution at Site 629 and Pueblo Alto (Table 2). Certain taxa with a restricted distribution in the Chaco area, such as pinyon pine and squawbush, were absent at Site 627. While corn remains were essentially ubiquitous at all of the Chaco sites, beans and squash were far more selective in their occurrence and were found in significantly fewer instances at Site 627. In terms of absolute quantities of seeds or percentage of samples found, Site 627 fell behind the other sites in almost every taxon. When only charred seeds are inspected in an effort to exclude the noise from possible modern contaminants, a similar pattern is found (Table 2).

Sample size was suspected to be a significant factor in determining the recurring differentiation between Site 627 and the other sites considered here. A steady increase in number of taxa encountered at a site is observed as the number of samples analyzed increases, with a levelling off point occurring between 20 and 30 samples (P. Minnis, personal communication). There is, of course, a good deal of variation between sites, attributable to differential preservation and other factors. In the Chaco case, however, difference in sample size refers more to productivity of the samples than to number of samples. For instance, although the number of samples analyzed at Sites 627 and 629 is nearly identical, the total number of seeds recovered varies by a factor of 10; 5000 seeds at Site 627, and 50,000 at Site 629. Pueblo Alto also has a higher average density of seeds per sample than does Site 627.

When species composition of whole site assemblages is examined, it is readily apparent that over 95% of all seeds found at the two canyon village sites belong to less than half a dozen taxa (all annual weeds), while the remaining approximately 20 taxa are each represented by less than 0.1% of the seeds. At Pueblo Alto, by contrast, only 8 of the 33 taxa recovered are represented by less than 0.1% of the seeds. Those taxa more abundant and widespread at Pueblo Alto than at either of the village sites include grasses (totaling 17% of all seeds, primarily ricegrass and dropseed) and several nonweedy economics (e.g., pinyon, hedgehog and pricklypear cacti, and saltbush).

While the initial view of these flotation records is one of one village site set in contrast to the second village site and Pueblo Alto, some significant differences between village and town assemblages begin to emerge, beneath the obscuring fog of postoccupational contamination and differential productivity of botanical artifacts. Both villages are very shallow sites (with the exception of pit structures) and subject to considerable alluvial erosion and deposition. While the great majority of seeds here are prime candidates for noncultural contaminant status (i.e., unburned and belonging to a handful of weed species common in the immediate site vicinity), carbonized seeds, clearly associated with village site occupation, follow a similar pattern. Hence, the prehistoric use pattern seems to be one of primary utilization of immediately available weed species, in company with agricultural products. At Pueblo Alto the depth of interior use surfaces can be measured in meters rather than centimeters, and a highly plausible case can be made for inclusion of many uncarbonized seeds in the prehistoric array. In several rooms a constellation of three to four economic weeds including goosefoot, pigweed, purslane, and in one case, stickleaf are repeatedly found, carbonized in heating features and uncarbonized on floors, in decreasing density with increasing distance from the concentration of food processing features. While local weeds form the backbone of wild food use, as at the villages, the species assignable to cultural activity is consistently more diverse at Pueblo Alto. The Pueblo Alto pattern more often includes taxa more common in habitats away from the site: squawbush from sheltered side canyons and talus slopes, and pinyon nuts, juniper berries, yucca and cacti from higher elevation mesa tops.

Further contrasts between village and town plant usage can be found in debris associated with specific feature types. Formal slab- or adobe-lined firepits exhibit distinctly different botanical assemblages compared to heating pits (shallow basins lacking evidence of intensive in situ burning) at village sites 627, 629, and also 299. With far greater regularity than other site locations such as floors, storage pits, and mealing areas, firepits (including several at a fourth village site, 724) are characterized by the presence of charred economic weeds and corncob fragments. Heating pits at the small sites contain practically no such remnants of probable food processing activities (Figures 1 and 2). At Pueblo Alto on the other hand, firepits and heating pits appear to have been used in very similar ways (Figure 3).

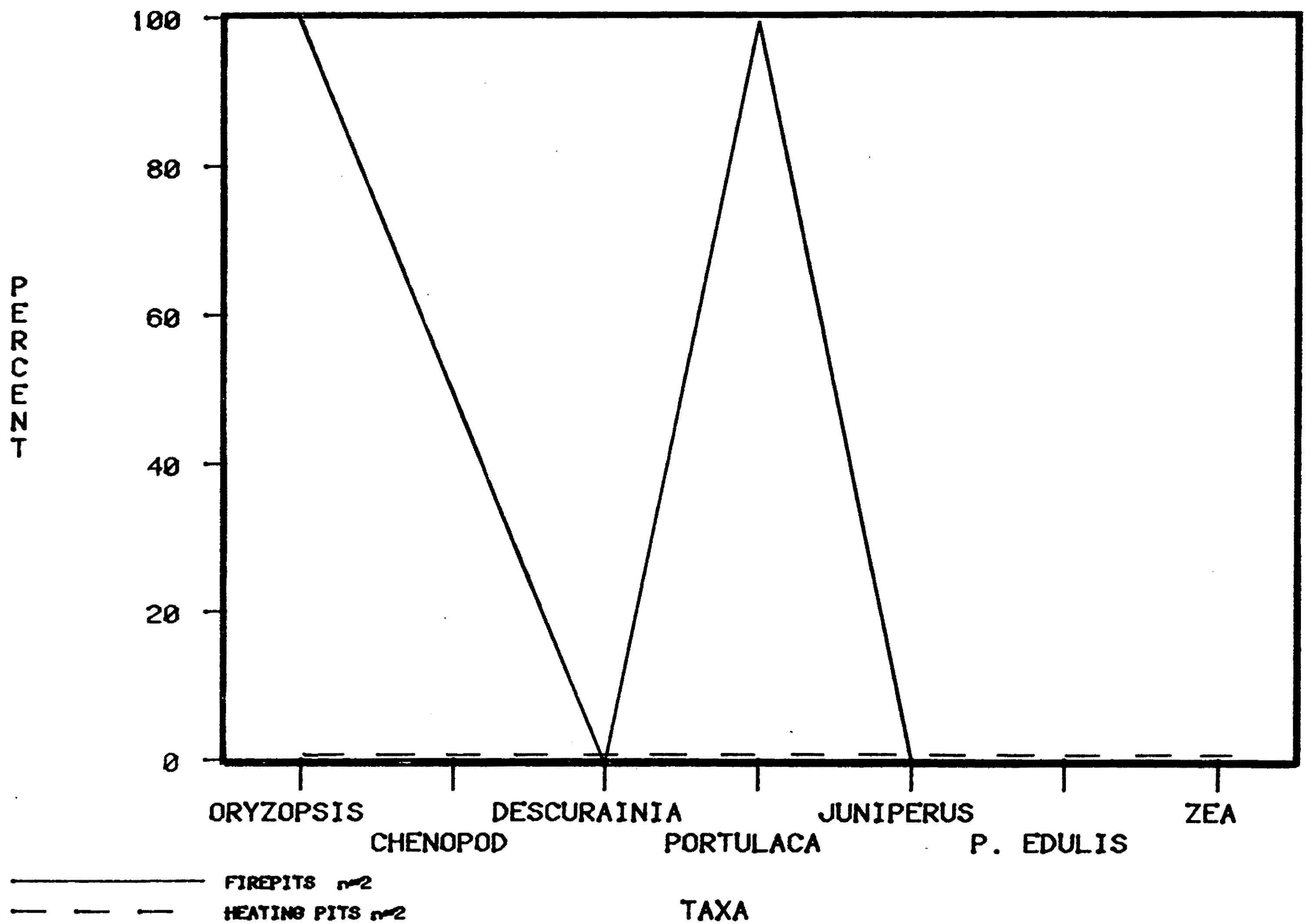

Figure 1. Percent of sampled features with charred remains of selected economic plants, Site 29SJ627. Solid lines are firepits, dashed lines heating pits.

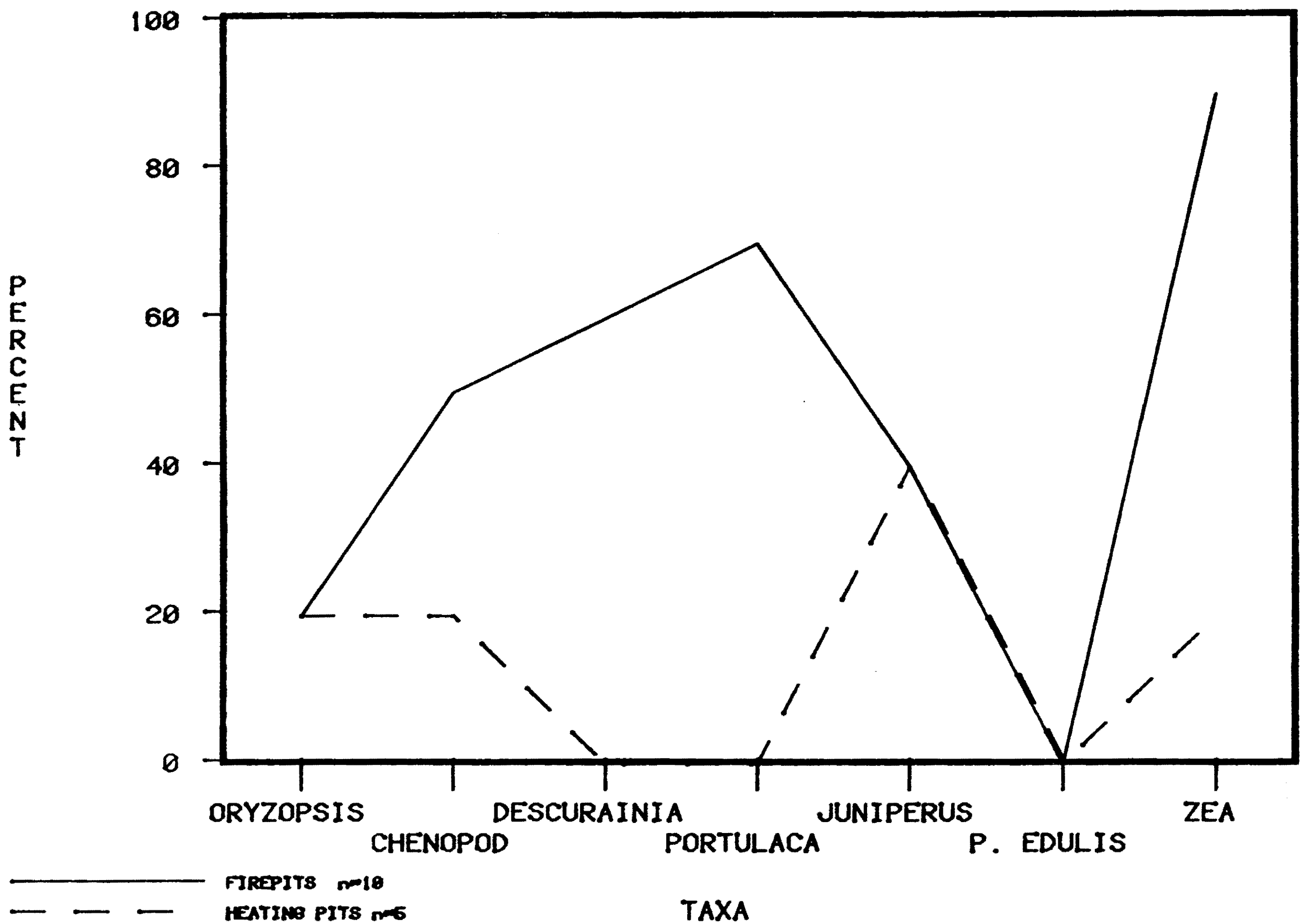

Figure 2. Percent of sampled features with charred remains of selected economic plants, Site 29SJ629. Solid lines are firepits, dashed lines are heating pits.

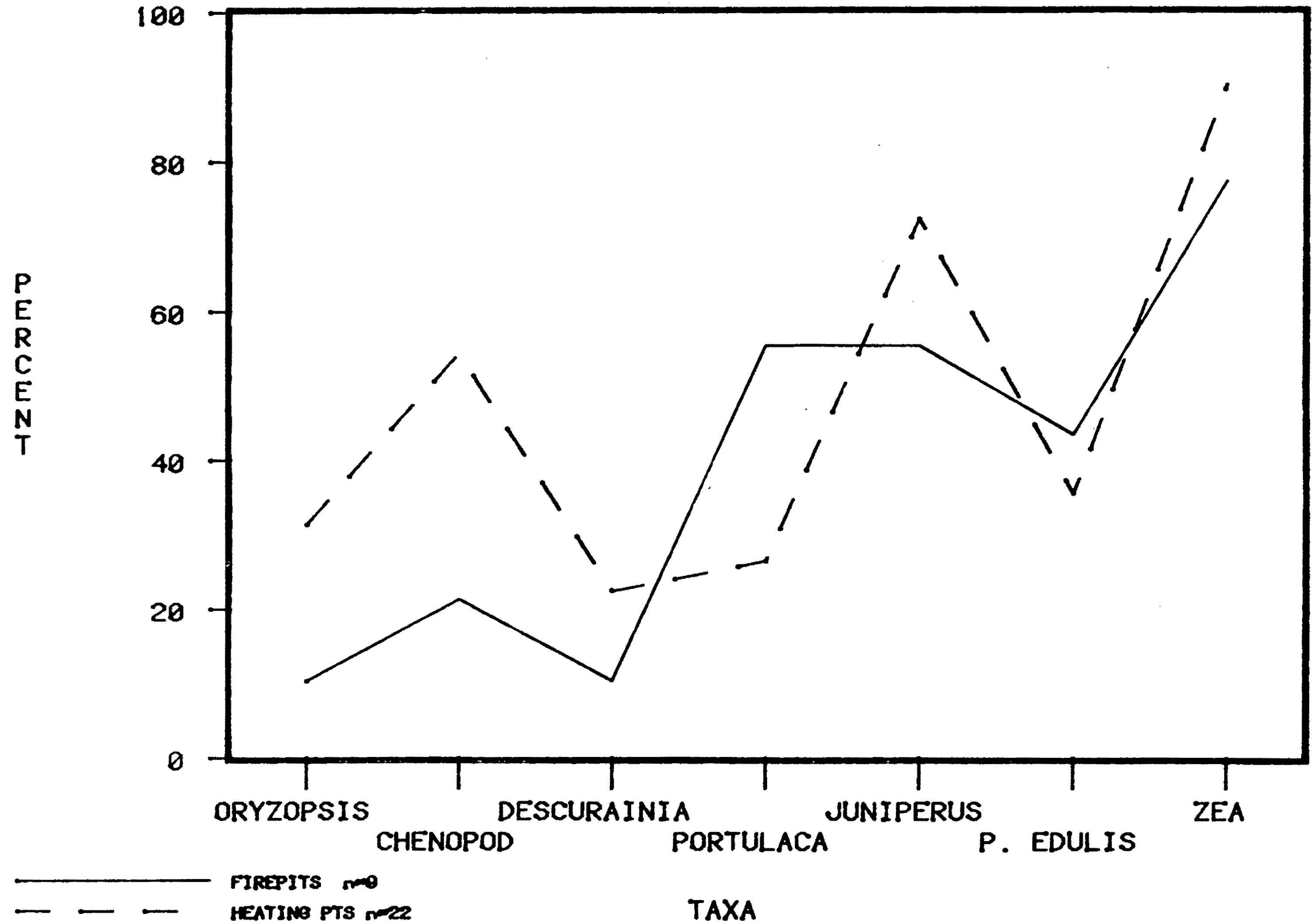

Figure 3. Percent of sampled features with charred remains of selected economic plants, Pueblo Alto. Solid lines are firepits, dashed lines are heating pits.

Again at Bis sa'ani, the great house of an outlying Chacoan community about 10 km northeast of Chaco Canyon (Doyel and others, this volume), flotation assemblages from both types of heating features are high in several types of charred economics, and therein differ notably from other site locations (Donaldson and Toll 1982).

Summary

The range of plant species exploited is shown to be slightly greater at a Chaco town, presumably reflecting greater access to resources common outside the canyon, including pinyon and pricklypear cactus. Household organization and subsistence activities may be different at town vs. village sites. Evidence for this depends on interplay between archaeological variables and feature use as determined by botanical debris. While taxonomic diversity could be related to sample size, controlling for this factor reveals that some real variability between site types exists. Perhaps it is of particular interest that the botanical assemblages at these very different but essentially contemporaneous sites are not more divergent than they are. The subsistence records show some fundamental similarities, both in dependence on locally available wild species and on corn agriculture.

As a final note, this discussion provides the caution that variability in the archaeological record due to noncultural factors may be of a much higher numerical order than more subtle and often contradictory differences that can be related to past behavior.

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THE DISTRIBUTION OF CORN POLLEN AT THREE SITES IN CHACO CANYON

Anne C. Cully

Abstract

Various botanical analyses of material from three sites in Chaco Canyon have been undertaken in an effort to broaden our knowledge of the subsistence base used by the prehistoric inhabitants and to explore possible differences with regard to the gathering, storage, and processing of plant resources at the three sites. The data reported here encompass the major site type distinctions that have been recognized at Chaco Canyon. One area of possible functional differentiation may have been in subsistence patterns. This paper is concerned with the results of pollen analyses that were undertaken at the three sites to find evidence of prehistoric storage and preparation of domesticated and wild plant foods. In spite of intrasite differences in the distribution of corn (Zea mays) pollen, the evidence suggests that corn was of equal importance in subsistence at two small village sites and the large structure of Pueblo Alto.

Introduction

Various botanical analyses of material from recently excavated sites in Chaco Canyon have been undertaken in an effort to broaden our knowledge of the subsistence base used by the prehistoric inhabitants and to explore possible differences in site function with regard to the gathering, storage, and processing of plant resources. As part of these botanical analyses, from 1975 to 1981 I processed and analyzed pollen samples from several small sites and one great house. Two of the small sites, 29SJ627 and 29SJ629, are located in Marcia's Rincon, west of the Fajada Butte. These two village sites are similar in overall plan. Site 627 is larger than 629, with more rooms resulting from several episodes of remodeling (Figures 1 and 2). Both structures have a back row of contiguous rooms that probably functioned, in part, for storage. During the early stages of construction these rooms were joined to a series of ramada rooms, characterized by low walls and a roof structure. At 627 the ramada rooms were subsequently remodeled into actual rooms, and additional ramadas were added in the next row. At 629 the original structure remained unmodified, but rooms were added at both ends of the site (Truell 1981; Windes 1978). Pueblo Alto (29SJ389) is a large Chacoan structure located about 0.8 km from Pueblo Bonito. Construction there took place in a series of seven stages (Windes 1981) and resulted in a complex unit very different from the small village sites (Figure 3).

Archaeological excavations over the years at Chaco Canyon have disclosed structures that vary greatly in size and construction. The large, complex sites like Pueblo Bonito and Pueblo Alto, which were built on a massive scale, have been described variously as towns, great houses, and more recently as simply large structures by Lekson (this volume). Small sites, described by Truell (1982) as "...modestly constructed single story houses...," are strikingly different from the large structures in plan and scale. Based on tree-ring and ceramic evidence, Hawley (Brand and others 1937) reports that sites of these two differing types were occupied contemporaneously. Conjecture about the differing functions of the smaller and larger sites with rega rerd to social organization and subsistence patterns has continued to the present day (Kluckhohn and Reiter 1939; Vivian and Mathews 1965; Windes 1978, 1981).

The data reported here encompass the major site-type distinctions that have been recognized at Chaco Canyon. One area of possible functional differentiation may have been in subsistence patterns. Pollen analysis can be an important tool in looking for evidence of prehistoric plant utilization (Hill and Hevly 1968; Dimbleby 1978; Bohrer 1972). Evidence of storage and preparation of domesticated and wild plant foods has been found in the form of pollen from many sites in the Southwest (Hill and Hevly 1968; Bohrer 1972, 1981; Weir 1976; Scott 1978, 1979; Adams 1980). In addition, Hill and Hevly (1968) attempt to define room function at Broken K Pueblo based on percentages of pollen grains from economic, or ethnobotanically

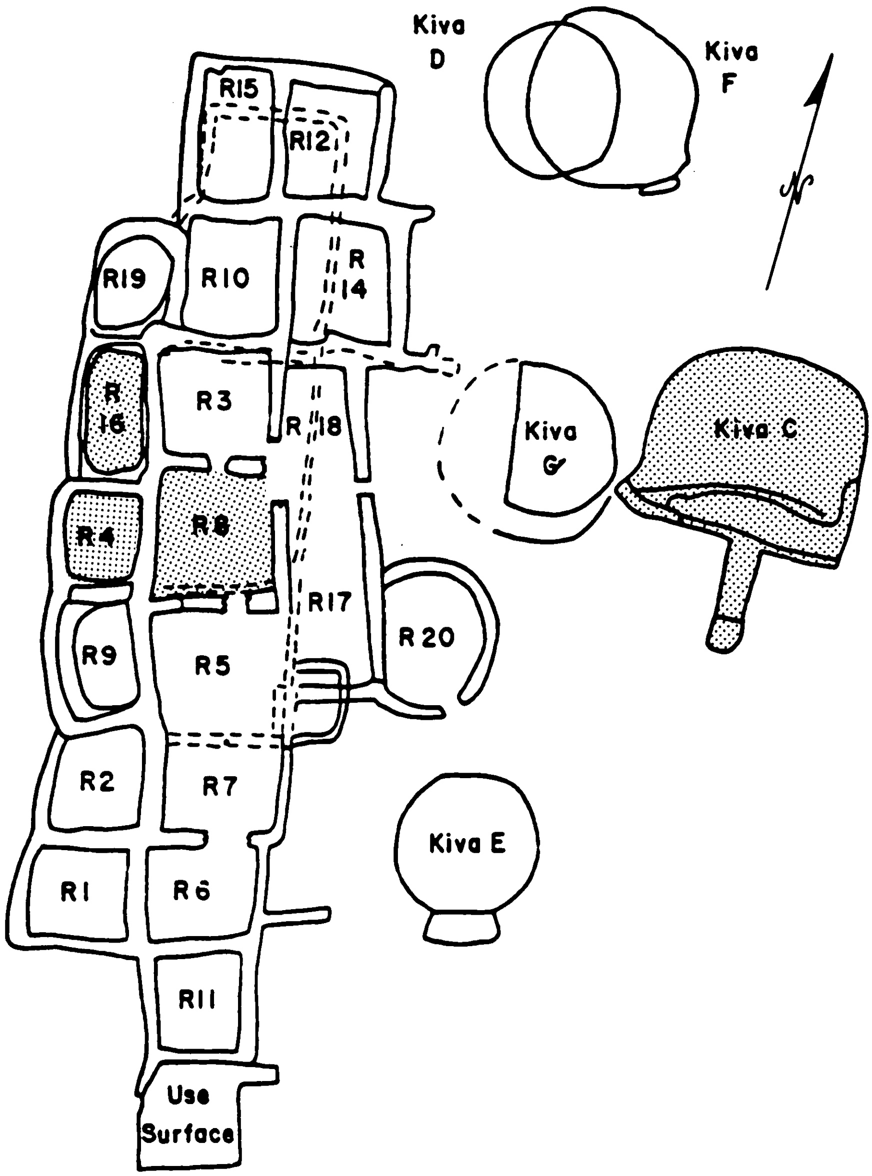

Figure 1. Site 29SJ627, Chaco Canyon (shaded areas indicate excavated rooms sampled for pollen analysis).

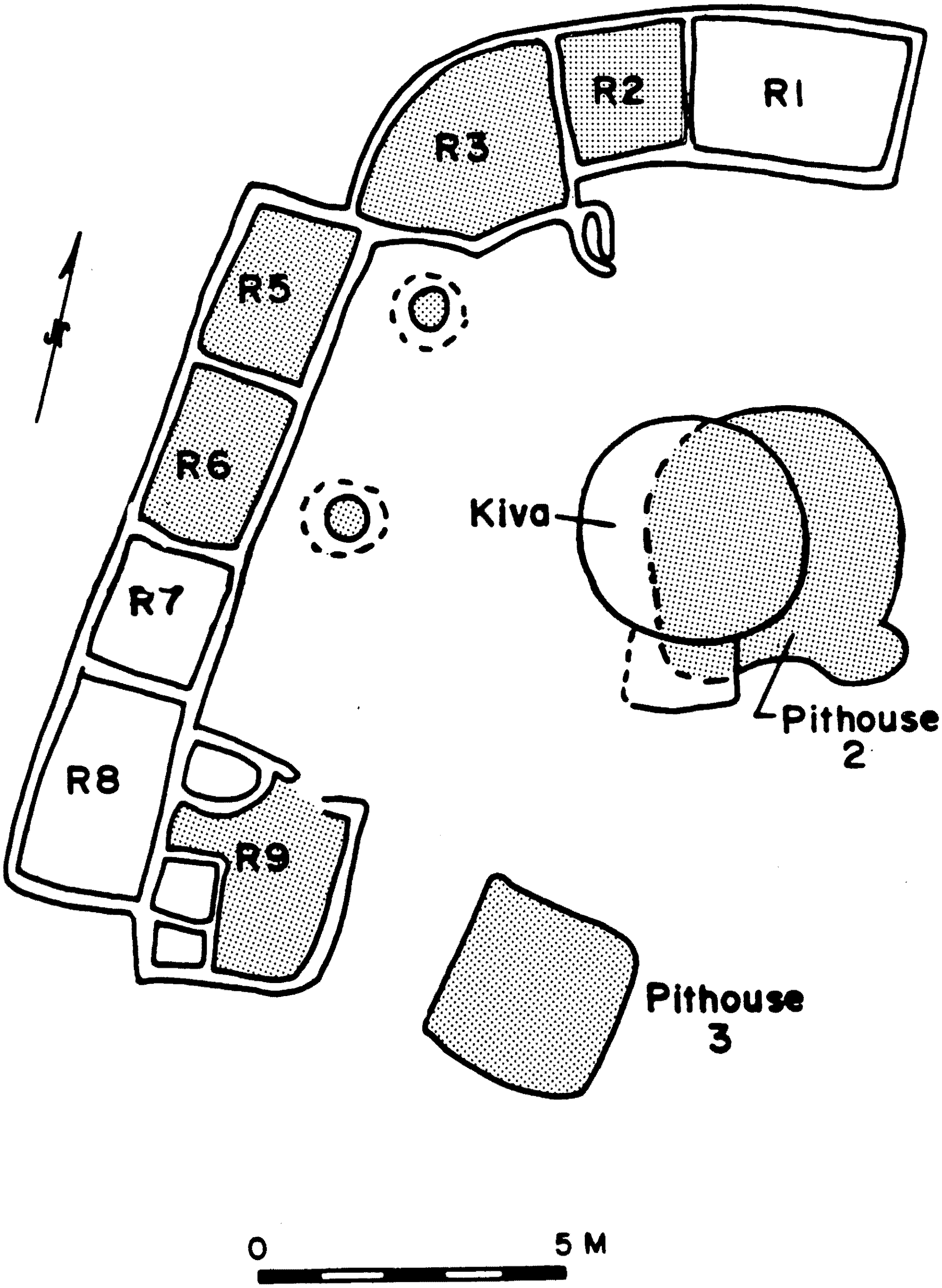

Figure 2. Site 29SJ629, Chaco Canyon (shaded areas indicate excavated rooms sampled for pollen analysis).

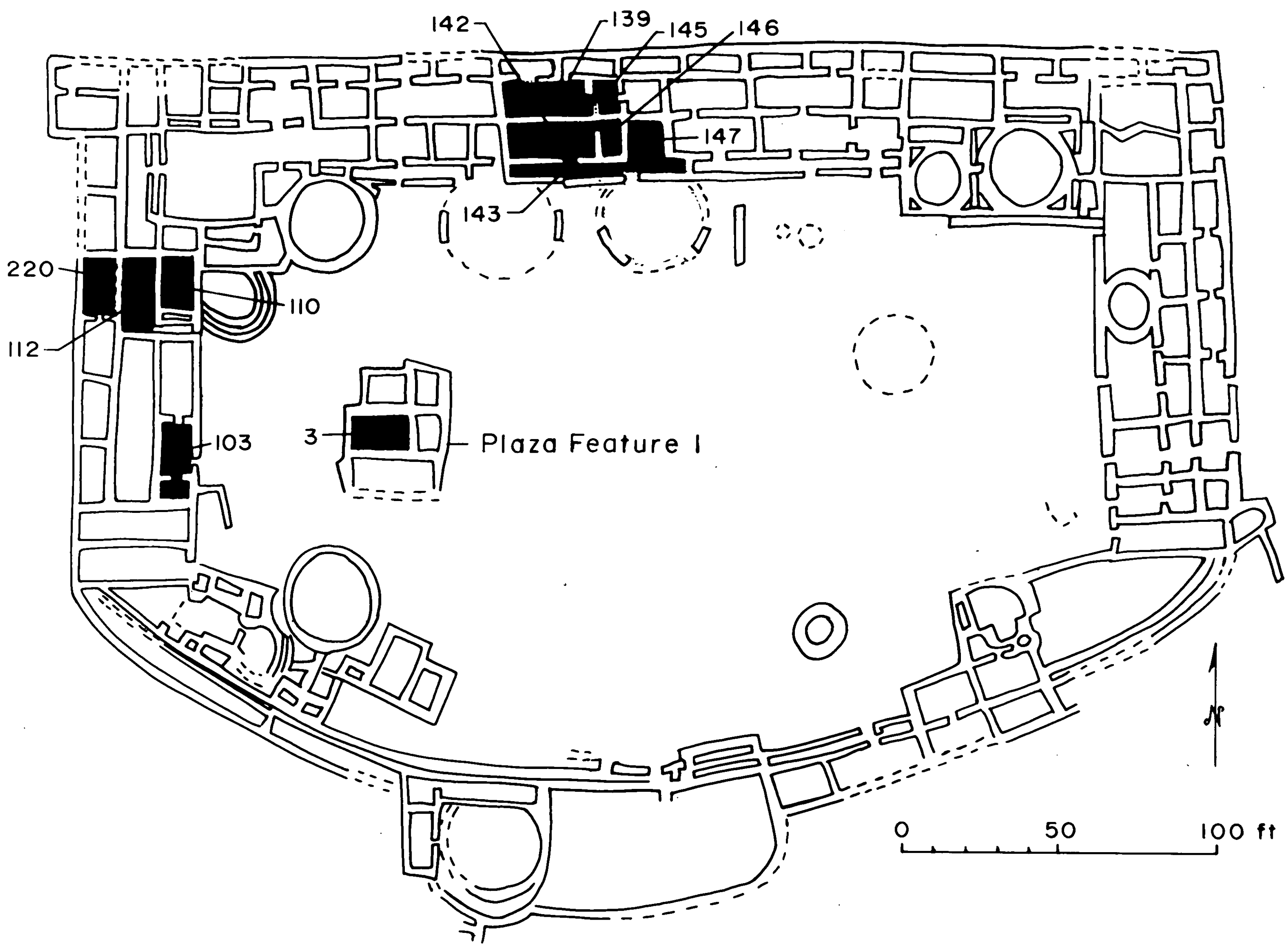

Figure 3. Pueblo Alto, Chaco Canyon (shaded areas indicate excavated rooms sampled for pollen analysis).

important, taxa from both domestic and wild plants. These taxa include pollen from corn (Zea mays) and squash (Cucurbita) as well as pollen from important wild foods, such as cactus, purslane (Portulaca), beeweed (Cleome) and others that are documented in ethnographic literature as being important to modern Indian groups in the Southwest. Pollen analysis has been used to reconstruct the past environment by using pollen samples from dated archaeological sites (Schoenwetter 1962, 1974; Schoenwetter and Eddy 1964; Hevly 1964; Bohrer 1972). Recently, cautionary reports regarding the inherent problems in sampling from archaeological sites have been written (Pippin 1979; Cully 1979; Hall 1981; Hevly 1981). Variability in results from pollen samples and differential preservation and the possibility of changes in local pollen rain due to man's activities have been noted. These factors may affect interpretation of the data regarding environmental changes.

Recent pollen analysis of the Chaco Canyon material has focused on methodological and ethnobotanical considerations. Careful consideration has been given to sampling techniques, particularly regarding the variability between pollen samples taken from several locations within the same level of excavation. After developing a sampling methodology that takes the factors of variability into account, I hoped to be able to identify rooms where activities of plant preparation and storage might have taken place and to make reliable comparisons between rooms within the same site and eventually between different sites.

Methodology

Field

In order to accomplish the goals decribed above, a sampling plan using a grid system was set up (Cully 1977; Truell 1981). Within this grid system each lettered grid was sampled for pollen. The grid could be used in rooms of any size, at any level of the excavation, at the floor fill, floor contact and subsequent floor levels. The same lettered grids were sampled at all levels. In this way different grid locations within the same level could be compared. Samples from each grid could be considered singly in order to assess the variability between samples and to determine if any particular locations in a room were utilized for storage or preparation of plants. The results from individual grid samples from a room could also be lumped, if necessary, to make comparisons between floors or between rooms within the site. All features were also sampled. Sampling in this way provided the opportunity to assess the variability within rooms and insured comparability between rooms and, later, between sites. This basic sampling plan was initiated during the second year of excavation at Site 627. With some modification this plan was used at Site 629 and Pueblo Alto. Initial work at 627 indicated that the floor contact level (from about 2.5 cm above the floor to a few mm into the floor surface) gave the best results; pollen from the floors themselves was poorly preserved and difficult to identify. Careful attention was given to the origin of the fill above the floors, as contamination from trash dumping could occur in sediments from the floor contact level and lead to erroneous conclusions about room function (Cully 1977). Samples from this level were processed and analyzed for Site 629 and Pueblo Alto, as well as from selected samples from features associated with the floors, such as mealing bins, storage pits, and firepits.

Laboratory

Groups of samples from the three sites were processed by the settling tube method, which is based on separation of particle sizes in a dispersing solution.

Ten g of sediment were weighed, ground in a mortar and pestle, and washed through 100-mesh screen in clean beakers. Five to 10 ml of 20% HCl were added to the beakers and stirred several times. When the bubbling action stopped, the sample in solution was transferred to test tubes, centrifuged, decanted, and rinsed. A dispersing agent was used to rinse samples back into beakers. The sample was mixed thoroughly with the aid of a magnetic mixer and poured into settling tubes filled with dispersing agent. After two minutes the large heavy sand grains had settled in the flexible tubing, and a clamp was placed above that part of the tube. After 19 hours the flexible tubing was removed and the sediment grains above the clamp associated with the pollen were removed into a test tube. Large sand grains and small clay and silt particles were left in the tube. The pollen-bearing portion of the sediment was treated with 40% HF in a hot water bath. Spot checks of the large sand grain portion and the silt and clay portion of the samples were made to make sure they did not contain pollen. The samples were placed in an acetolysis solution and then in a hot water bath. After this the remaining portion of the samples was rinsed, placed in glass vials, and slides were prepared using a glycerin mounting medium.

Following Barkley (1934) I attempted to count 200 pollen grains for each sample in order to reach the maximum number of taxa and ensure comparability between samples.

Terminology follows Field Guide to Native Vegetation of the Southwestern Region (USDA 1978) and A Flora of New Mexico (Martin and Hutchins 1980). Pollen identifications were made using How to Know the Pollen and Spores (Kapp 1969), and reference collections maintained by the Castetter Laboratory for Ethnobotanical Studies at the University of New Mexico.

Results

Room Function

Based on structure and features at Broken K Pueblo in Arizona (Hill and Hevly 1968), three types of rooms were distinguished. Habitation, or living rooms, were characterized by firepits and mealing bins. Storage rooms did not contain these features. Kivas were distinctive ceremonial rooms, round in shape with characteristic pilasters and benches, central firepits, deflectors and vents, loom anchor holes, and southern recesses. In Chaco Canyon, nonceremonial rooms seem to fall into the basic dichotomy described at Broken K Pueblo. At Pueblo Alto, distinctions could be made between such rooms based on presence or absence of features. At the two smaller sites, these distinctions were not so clear but were still evident (Windes 1978; Truell 1981). At these small sites, subterranean rooms sometimes contained features indicating mixed living and ceremonial functions. Kivas were distinguished from other room types at both the small and large sites by architecture and features (Windes 1978, 1981; Truell 1981).

In this study I looked at the percentage of corn pollen (and other economic pollen types that will be reported elsewhere [Cully 1983]) in storage, living, and subterranean rooms as defined at the three sites. Corn pollen is large (>70 microns) and unlikely to be distributed a great distance from the growing site (Raynor and others 1972). The presence of corn pollen may serve as a kind of index of storage and processing activities occurring in an archaeological site. Bohrer (1972, 1981) has shown that corn pollen could have been brought into a site on parts of the corn plant, especially tassels and husks. Ethnographic evidence indicates that corn pollen may have been used for ceremonial purposes in the past as it is used by modern Indian groups (Stevenson 1904; Cushing 1920; Stephen 1936; Lange 1959).

Storage And Living Rooms

At Site 627 corn pollen was found in the same relative abundance in both storage and living rooms (Figure 4). This was also true at Pueblo Alto. At Site 629 relative abundance is very low in both room types. There are no apparent patterns of higher percentages of corn pollen in one of these room types than another.

Pit Structures And Kivas

At Site 629 corn pollen was found in extremely high percentages in Pithouse 3 (Figures 4 and 5). Other pithouses and kivas sampled at the three sites in Chaco Canyon did not contain high percentages of corn pollen (Figure 5).

Site Comparisons

There are no patterns of distribution of corn pollen based on village vs. town site types. Pueblo Alto and Site 627 are similar in the distribution of corn pollen in living and storage type

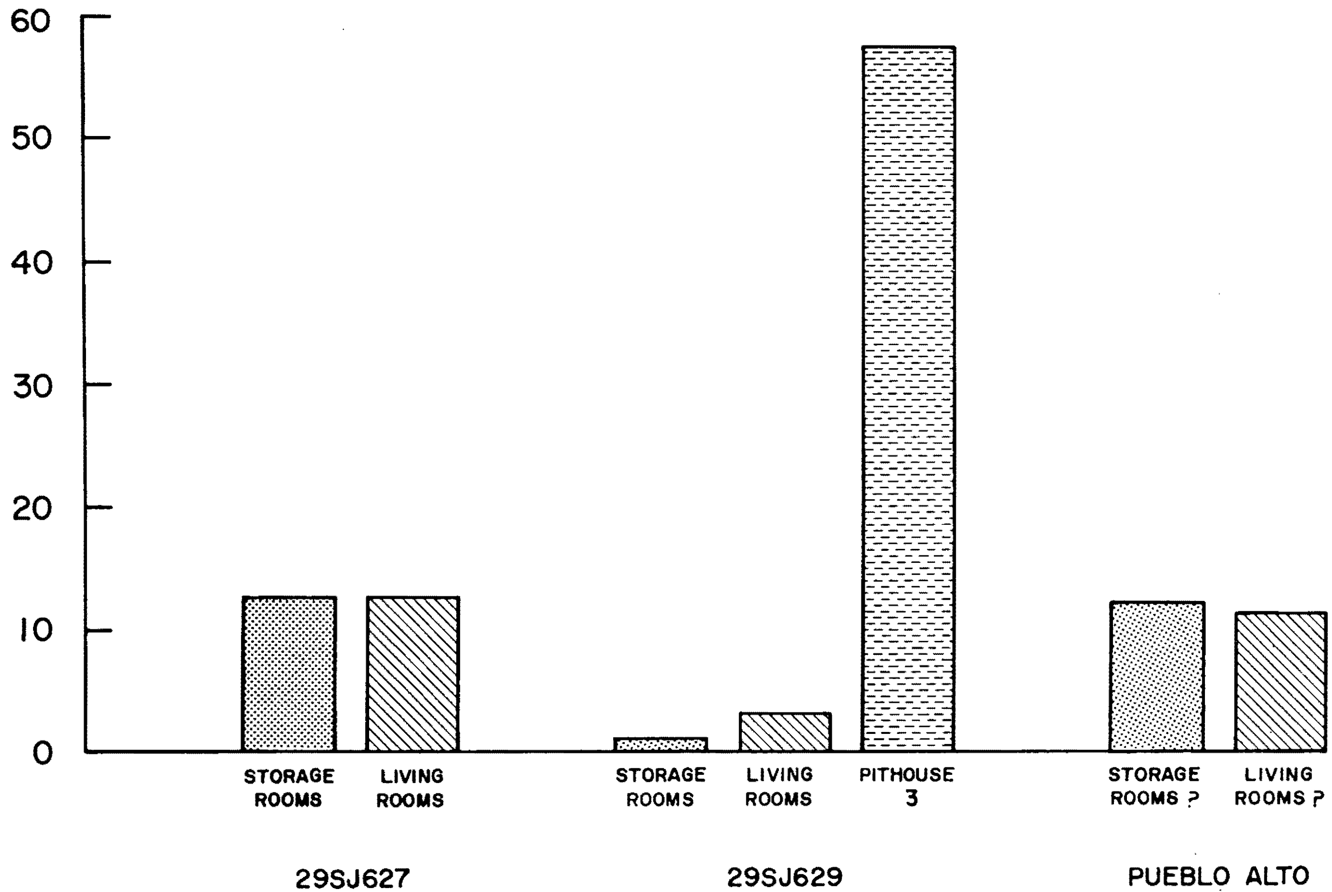

Figure 4. Corn pollen percentages from storage, living, and pithouse rooms; Sites 29SJ627, 29SJ629, and Pueblo Alto, Chaco Canyon.

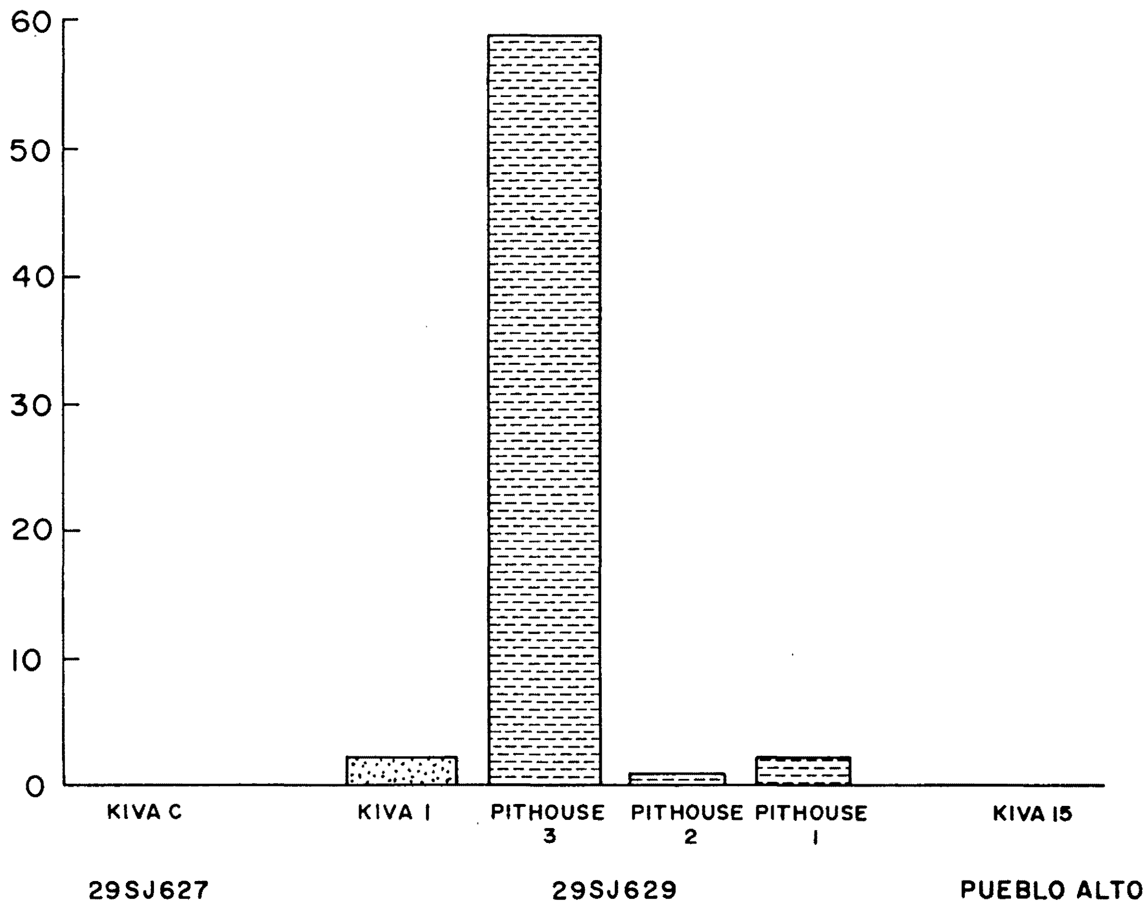

Figure 5. Corn pollen percentages from kivas and pithouses; Sites 29SJ627, 29SJ629, and Pueblo Alto, Chaco Canyon.

rooms; Site 629 is different in that corn pollen percentages are very low in both room types (Figure 4). Pollen counts from all the samples from each site were summed and treated as one inclusive pollen sample. The relative percentage of corn pollen was then calculated for each site overall. Figure 6 indicates that the relative corn pollen percentages for each site are almost the same, leading to the conclusion that corn played an equally important role at all three sites; whether for immediate consumption, storage, or ceremonies is not clear.

Discussion

Corn pollen could have been introduced into the three sites in several ways, such as storage of corn after harvesting, or the use of corn pollen for ceremonial purposes. Ethnographic descriptions of harvesting and storage at Zuni (Cushing 1920) and Hopi (Whiting 1939) relate that corn was picked from the field, then husked and stored. White (1944) describes the Keres roasting and storing corn ears with the husks on. The Navajo pulled six complete corn stalks from the field prior to harvesting and placed them according to the cardinal directions on the spot where the ears were to be stored (Hill 1938). Bohrer (1972) has shown that such harvesting, storing, and processing activities could have resulted in dispersal of pollen into archaeological sites.

However, there is also ethnographic documentation for the ceremonial use of corn pollen. At Cochiti, Lange (1959) describes the women of the pueblo gathering corn pollen from green corn plants and storing it in jars. Hill (1938) describes the Navajo gathering corn pollen when it first appears on the corn and saving it for ceremonial use. Cushing (1920) and Stevenson (1904) describe the Zuni as ritually blessing seed corn with corn pollen and making corn meal and pollen paintings on the floors of rooms during ceremonies and in rooms used for storing ceremonial objects. Stephen (1936) cites numerous examples at Hopi of the uses of corn pollen in ceremonies in kivas and in food packets attached to prayersticks. Corn pollen was used in blessing objects, and a little was included with tobacco in cane cigarettes.

High relative percentages of corn pollen in archaeological sites have often been interpreted as being the result of the introduction of corn that was being processed or stored (Hill and Hevly 1968; Fish 1981). Fish (1981) interprets high percentages from floors or feature samples as evidence of primary introduction immediately after harvesting. After this initial introduction, pollen dispersal presumably decreases as the corn is moved about from one location to another. High percentages of corn pollen also occur in mealing bins that were used for processing corn into meal (Hill and Hevly 1968; Bohrer 1980; Cully 1982).

High percentages of corn pollen are rarely found in kivas. At Broken K Pueblo, Hill and Hevly (1968) found low percentages of economic pollen types (including corn) in kivas. At Chaco Canyon, kivas are also low in corn pollen (Figure 5). A sample from a kiva at a small site near Bis sa'ani Pueblo (about 15 km from Chaco Canyon) did not contain any corn pollen (Cully 1982). Scott (1979) found this to be true at Dominguez Ruin in southern Colorado. At Salmon Ruin in northwestern New Mexico, however, Bohrer (1980) interprets high percentages of corn pollen as the result of medicinal and ceremonial uses. Corn pollen was found in high percentages (and sometimes in clumps or aggregates) in storage rooms, living rooms, and in two kivas at Salmon.

There are several possible explanations for the presence of corn pollen in the three sites sampled at Chaco Canyon and for the high percentages from samples taken at Pithouse 3 from Site 629. They could result from primary storage or processing of corn or from the ceremonial use of corn pollen. It seems most likely that the pollen found in the aboveground structures was deposited as the result of processing and storage rather than ceremonial activities. This may also be the explanation for the extremely high percentage of corn pollen at Pithouse 3. This subterranean structure could have been the location for the primary storage of corn immediately after harvesting. As Truell (1982) points out, prior to the mid to late 1000s food preparation and related activities were carried on in pit structures associated with the small sites. After this time features associated with these activities were no longer common in subterranean rooms, which presumably were being used mainly as kivas. Pithouse 3 at Site 629 was apparently not used as a kiva. It was abandoned shortly before the final occupation of the aboveground rooms and was never remodeled to

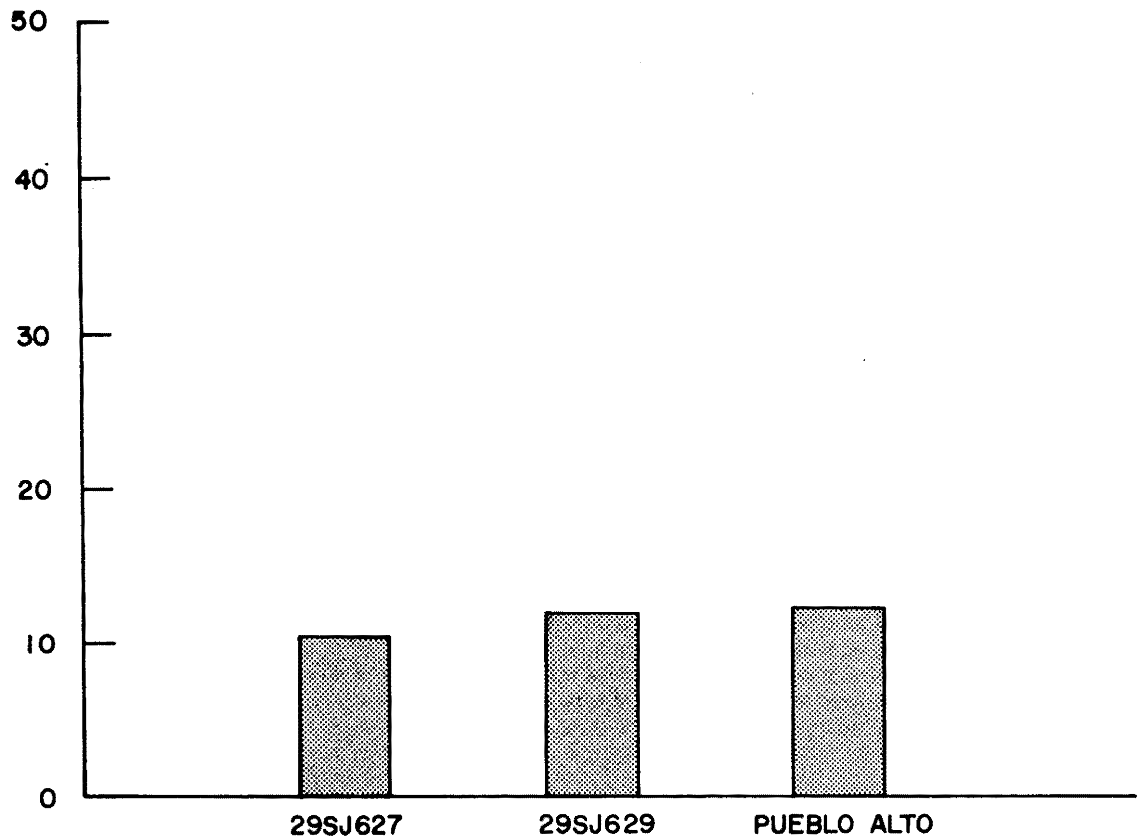

Figure 6. Total corn pollen percentages from Sites 29SJ627, 29SJ629 and Pueblo Alto, Chaco Canyon.

have the characteristics of a kiva (Windes 1978). Windes (1978) believes that Site 629 may have been occupied seasonally, and the pattern of use of living, storage, and kiva structures consequently was not developed as it was in sites that were used year-round.

Pollen evidence for initial storage has also been found at a small site near Bis sa'ani Pueblo. The corn pollen percentage from a floor sample at MN-G-63-23 was 95% (Cully 1982). The small sites were occupied contemporaneously with the large structure of Bis sa'ani Pueblo and are thought to have been located near agricultural fields (Cully and others 1982). The initial or primary storage of corn from nearby fields would be quite likely at these small sites.

Conclusions

At Chaco Canyon no distinct patterns of distribution of corn pollen have emerged based on comparison of data from small and large sites. One of the small sites (627) and the large structure of Pueblo Alto are similar in relative abundance and in distribution of corn pollen in storage, living, and subterranean rooms. At the other small site (629), pollen percentages are low in aboveground rooms but extremely high in one pithouse structure. In spite of these intrasite differences, the pollen evidence indicates that corn was of equal importance in subsistence at all three sites. While this evidence is certainly not comprehensive enough to conclude that subsistence patterns were identical at small and large sites, it suggests this to be the case. Site 629 may have been occupied seasonally with initial storage and processing of corn being carried out in Pithouse 3.

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ANASAZI DIET AND SUBSISTENCE AS REVEALED BY COPROLITES FROM CHACO CANYON

Karen Husum Clary

Abstract

An analysis of coprolites (human feces) from Chaco Canyon was undertaken to examine dietary patterns of Classic Period prehistoric Anasazi inhabitants of Chacoan pueblos. Faunal, palynological and macrobotanical remains were analyzed, described and evaluated. From the analysis it appears that the diet was composed largely of small mammals such as rabbits, prairie dogs, and rodents, cultivated plants such as corn and squash, and edible weeds that grow in response to cultivation and human disturbance. Wild plants were consumed to a lesser degree. This pattern is very similar to the diet described from two other large Southwestern Anasazi pueblos and may represent a regional subsistence pattern.

Introduction

The study of coprolites from Chaco Canyon was undertaken with several objectives in mind. The first was to examine the diet of Chaco Canyon inhabitants during Pueblo II and Pueblo III times. Information about prehistoric Chacoan diet could be applied to the understanding of resource utilization and reflect the nature of social organization and adaptation of Chacoan society to a marginal environment.

The second was to compare subsistence between two large Chacoan sites, Pueblo Bonito and Pueblo Alto. Coprolites were dated by association with the building phases of the rooms or by ceramic associations of the trash mound layers from which they were recovered. Most coprolites from Pueblo Alto were recovered from the postoccupational fill of rooms, though some were from trash-filled pits contemporary with the period of occupation (William Gillespie, personal communication). Coprolites from Pueblo Alto were recovered in the 1970s by the Chaco Center, National Park Service. Coprolites from Pueblo Bonito were recovered by George Pepper and the Hyde Expedition, American Museum of Natural History, during the late 1800s. Archaeological control of the proveniences were more precise with the later excavation. Records revealed that the Pueblo Bonito coprolites were collected from the debris in rooms (Table 1).

It was of interest to determine whether differences or similarities in diet could be distinguished between the two sites. Pueblo Alto coprolites (22) were recovered from Rooms 110 and 103, from the Trash Mound, and from Plaza 2. The coprolites from Pueblo Bonito (13) were recovered from Rooms 24, 25 and 107.

The third objective was to compare Anasazi subsistence in Chaco Canyon to that of other Anasazi sites of similar time periods. Antelope House, Canyon de Chelly, Arizona (Fry and Hall 1975; Williams-Dean and Bryant 1975; Kelso 1976), and Hoy House, Johnson Canyon, Colorado (Stiger 1977; Scott 1979) were selected for comparison because faunal and ethnobotanical information were available.

Ingestion, Digestion, Elimination

Studies of human digestion have shown that coprolites may represent one to five days' ingestion (Williams-Dean 1979:120-121). Ordinarily, 80% of the residue, including bone chips and pollen, from any one meal is eliminated by the end of the fourth day, although the rate may vary markedly (Alvarez and Freedlander 1924:578). Modern studies of experimental pollen ingestion indicate that while coprolite analysis is useful in dietary reconstruction, it is not useful in reconstructing individual meals because the movement of residues through the digestive tract is unpredictable (Williams-Dean 1979:159-161). The pollen of consumed plants progresses through the digestive system at variable rates. Elimination of pollen types varies according to the size and sculpture of

Table 1. Time period, provenience data, and sample numbers of Chaco coprolites.

Site	Time Period	Provenience Data	Sample No.
Pueblo Alto	1050-1100	Room 110, below floor 1, pre-floor and trash filled pits	3,4,5,6 7,8,9,10 11,12
		Trash mound, stratigraphic column 5, 15,17,18,19 grid 238, near top	15,17,18,19 20,21,24
		Trash mound, grid 262	51
	1100-1150	Plaza 2, grid 201, south stairs OS5	1,2
	post-1100	Room 103, post-occupational fill	13,14
	N=22		
Pueblo Bonito	920-1020	Room 107, debris in room	45,46,47
	1080-1130	Room 24, debris in room	35,36,37,38
		Room 25, debris in room	39,40,41,42 43,44
			N=13

the pollen grain. Larger grains may be excreted after ingestion without being retained in the digestive tract while others may be retained and appear in groups of specimens long after initial ingestion. Isolated grains may appear many specimens after the majority of a pollen type has been eliminated (Williams-Dean 1979:155-158). In general, though, it has been shown that pollen frequencies vary within the feces depending on the length of time since ingestion (Kelso 1976:58-60). A relatively large amount of an economic pollen type recovered from a coprolite may indicate ingestion of that type since the previous fecal passage. Relatively smaller amounts of the same pollen type may indicate only that ingestion occurred sometime in the past. Complete absence of a pollen type may indicate that the pollen has not been ingested during the preceding five- to seven-day period (Kelso 1976:58-60). This information was useful in assessing the importance of certain economic plants to the diet of the Anasazi.

Sample Preparation

Fragments of coprolites rather than complete specimens were recovered from the Chaco Canyon excavations. At Pueblo Alto, the coprolite fragments were collected, stored individually, and, when processed, treated as individual samples. Sample size varied--composite samples weight 15 g. For samples from individual specimens, one half of the sample weight up to 15 g was used. The other half of the sample, longitudinally split, was saved for future analysis.

In an archaeological context, information about the diet of individuals might be ascertained when entire coprolites are available for study and large, dateable, coprolite deposits such as latrine areas are sampled. In this study, it is not possible to view the results in this manner. Further, because selection was not random and the number of samples is small, I do not feel that the information derived from the analysis is representative of the total population that occupied the sites. Instead, the analysis of these samples gives insight into some of the plants and animals that were useful, available, and consistently eaten by some site inhabitants over relatively short periods of time.

The samples were rehydrated with a 0.5 percent solution of trisodium phosphate and distilled water. Determination of human origin was based on visual inspection before hydrating and by observing color changes in the rehydrated fecal liquid. If the solution turned a brownish-black color and was opaque, it was considered to be human (Callen and Cameron 1960; Bryant 1974b; Williams-Dean 1979:88-91).

After rehydration for 24 hours, the samples were gently shaken to disaggregate the fecal material and poured on a 180-micron mesh screen. Macroremains such as bone and plant parts were extracted for analysis (Toll 1981; Gillespie 1981) as were insect parts, charcoal, and sandstone grit from grinding tools. Tests were made for parasites, but results were negative (D. Duszyinski, personal communication). Pollen was extracted from the liquid that passed through the sieve by using a sequence of chemicals: hydrochloric acid to remove carbonates, hydrofluoric acid to remove silicates, and a mixture of acetic anhydride and sulfuric acid to remove the organic fraction other than pollen. The pollen was placed in glycerin, stained with safranine, and mounted on microscope slides. Relative pollen frequencies were obtained from those samples that yielded a minimum of 200 pollen grains (Barkley 1934) (Table 2).

Results

Faunal Analysis

The abundance of bone from small mammals and birds in these samples suggests that protein requirements were to a large extent fulfilled by the consumption of those species. Seventy-one percent of the samples contained small faunal bone fragments and 1,305 specimens of bone were noted (Gillespie 1981). Of course, the samples are biased against bone of large animals, since these are not as easily consumed. A comparison of economically useful animals identified from Pueblo Alto excavations (Akins 1982) demonstrated that large mammals as well as several species of birds played an important role in Anasazi subsistence. Of the taxa known to have been economically utilized, only a few are found in the coprolites (Clary 1983). For example,

Table 2. Percentages of pollen grains in human coprolite samples from Chaco Canyon. Symbol 'x' indicates presence of less than 5% in a sample. Symbol '-' indicates identification of a taxon to family level only.

		PUEBLO ALTO																						PUEBLO BONITO												
	Taxon / LAB. NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	17	18	19	20	21	24	51	35	36	37	38	39	40	41	42	43	44	45	46	47
CULTIVARS	Zea mays	9	72	12	+	x	91	7	x	x	99	x	27	x	x	33	54	67	x	92	11	x	15	43	x	x	x	+	97	87	x	+	28	+	+	+
	Cucurbita sp.	14	+		6		6																					+					+	+	+	+
EDIBLE WEEDS	Cheno-ams	36	9	64	4	x		8	x	x		x	45	x		67	+	5	x	+	17	x	10	9	x	x	x	7	+	+	x	54	31	22	8	+
	Sphaeralcea sp.									x		x		x							27															
	E.S. Compositae																																			
	Inc. Helianthus sp.	+	+	+	+	x		+				x	+	x			+	+	x		+		+	+	x		x	43		+	x	9	6	+		+
	L.S. Compositae	+	+	17	+			+	x				8	x	x		+	+			+	x	+	+	x		x	29		+	x	12	6	7	+	+
	Cleome sp.	+	+	+									+	x		+							70	35	x			+	+	+	x	+	+		+	62
	Eriogonum sp.					x																														
	Portulaca	14									x												+					+	+		x		+			
EDIBLE WILD PLANTS	Gramineae	+	+		81	x	+	81	x	x			+	x			14	8	x	+	10	x		+	x				+							
	Pinus edulis	+	+	+		x							6			+	+	+	x	+	+				x						x		+	+	+	
	Ephedra sp.			+	+	x			x			x	+	x							+				x							+	+			
	Yucca sp.	+								x																								+		
	Celtis sp.	+	+					+									18	+			+															
	Opuntia sp.																								x										+	
	Type A Cactaceae																								x				+				+	+		+
	Type B Liliaceae																																		82	
	Ribes sp.																+	12			+															
	Carex sp. (cf.)																				14															
NON-ECONOMICAL PLANTS	Pinus ponderosa												+					+			+			+				+						+	+	
	Salix sp.	+																														+		+		
	Quercus sp.												+																							+
	Rhamnus sp.																																			
	Artemisia sp.	+		+									+								+										x	+	+	+	+	+
	Rhus sp.																				+															
	Juglans sp.												+				+				+															
	Sarcobatus sp.			+													+	+			+										x	+	6	+		
	Fraxinus sp.	+											+																							
	Betula sp.											x													x											
	Ulmus sp.					x											+			+	+															
	Abies sp.	+				x							+																					+		
	Juniperus sp.																											+				+	+	+	+	
	Polygonum sp.									x																		+								
	Penstemon sp.																																			
	Vernonia sp.																																			
	Rumex sp.	+																																		
	Oenothera sp.																				+															
	Convolvulus sp.																								x											
	Plantago sp.																																+			
	Leguminosae	-											-				-	-						-				-		-			-	-	-	
	Ulmaceae	-																																		
	Umbelliferae							-																-											-	
	Liliaceae							-																												
	Unknown Types	7			+			+	x			x		x								+		+			+	+		+	x	+	+	+		
	Total Percent	100	100	100	100		100	100			100		100			100	100	100		100	100		100	100				100	100	100		100	100	100	100	100
	Total No. of Grains	265	243	240	220	29	220	233	63	44	202	69	200	35	5	200	200	200	30	200	200	65	247	239	60	9	14	220	233	223	39	200	217	212	215	221

Akins (1982:8-10) identifies a total of 65 economically useful taxa, while in contrast, three taxa, all of which were small mammals, were found in the coprolites from Pueblo Alto (Clary 1983:76).

Also detected were food preparation and consumption habits. Meat and bone from all parts of the bodies of small game were eaten (Gillespie 1981). Three genera were identified: Cottontail (Sylvilagus cf. audubonii), prairie dog (Cynomys gunnisonii) and deer mouse Peromyscus cf. maniculatus). Remains of a small bird, possible a horned lark, were also encountered.

Cottontail bone is the most abundant identified bone. Most of the unidentified bone is "rabbit-sized" and is most likely cottontail as well. No more than one individual rabbit could be recognized in any one sample. In some samples, abundant cranial, axial, and limb fragments and small articulated sections such as wrist joints suggest that entire rabbits were eaten (Gillespie 1981). Discolored or "cooking brown" bone indicates that some were boiled or heat treated. Heat softens bone and permits easier chewing and breakage, and an abundance of discolored bone in some samples may be due to easier consumption.

Summer consumption is suggested in one sample from Pueblo Alto by the presence of a juvenile prairie dog. In the same sample remains of an adult prairie dog were also found. It is of interest to note that only cranial parts are present, and they show no sign of having been cooked. There is also evidence for the consumption of entire deer mice (Gillespie 1981).

Macrobotanical Analysis

In comparison to other macrobotanical samples from Chaco Canyon, plant parts retrieved by dry sorting include a narrow range of wild and cultivated taxa (Toll 1981). This is due in part to small sample size, the lack of wet sorting of the samples, and food preparation methods such as grinding.

Plants recovered include the remains of cultivated plants such as corn (Zea mays) and squash (Cucurbita sp.); weedy plants that are useful for food such as tansy mustard (Descurainia sp.), purslane (Portulaca sp.), nightshade (Solanum sp.), and wild sunflower (Helianthus sp.); and wild or naturally occurring useful plants such as rice grass (Oryzopsis sp.), dropseed (Sporobolus sp.), and pinyon (Pinus edulis) (Toll 1981).

Pinyon nutshells were the most commonly retrieved food remain. According to Toll (1981), wild sunflower remains found at Pueblo Bonito are of particular interest as it is now apparent that human consumption of the small wild sunflowers produces a pattern of degradation similar to that produced by rodents. Shredded sunflower achenes found during macrobotanical analysis at Chaco sites have previously been regarded skeptically, as they were nearly always unburned and occurred along with rodent scats in proveniences known to be rodent disturbed (Toll 1981).

Ricegrass and dropseed were recovered in small quantities. In contrast, they are the two most commonly retrieved grasses from Chaco Canyon flotation samples (Toll 1981). Cultivars were represented by squash seed fragments and were common in two Pueblo Bonito samples (Toll 1981).

Pollen Analysis

More edible plant types were encountered in the pollen analysis than in the macrobotanical analysis. When combined, the pollen and macrobotanical data suggest a wide range of plant utilization. It is of interest to note that the macrobotanical record yielded taxa that were not found in the pollen record, and likewise, the reverse is true. Complementary evidence from the macrobotanical analysis was useful in the identification of a high spine composite (sunflower) as genus Helianthus, and identification of two grasses as ricegrass and dropseed.

All of the edible pollen types have been found in noncoprolitic pollen samples from archaeological features at Chaco Canyon (Cully 1977:55-69). The presence of these taxa in coprolites allows us to determine which of the range plants available were favored by site inhabitants and were eaten regularly. In order to determine this, three criteria were used. The number of times a taxon occurred in a group of samples, known as frequency of occurrence, or ubiquity, was noted. Pollen occurring in numbers substantially greater than it would in a soil sample was an indication that the plant had been consumed. For example, although globemallow (Sphaeralcea sp.) is a common constituent of pollen samples from surfaces and archaeological features in the San Juan Basin, it occurs in relative frequencies of less than 2% (Cully 1981:20, 1982a, 1982b; Cully and Clary 1981; Clary 1981a:5, 1981b). Globemallow is insect-pollinated and produces relatively little pollen per flower. As a component of the pollen rain it can be expected to occur in small numbers in soil samples. In contrast, it attains concentrations up to 27% in coprolite samples.

The amount of each pollen type considered substantial may differ from one species to another since production of pollen varies between species. Aggregates (Leroi-Gourhan 1975), or clumps, of undispersed pollen were also noted. The presence of aggregates could be indicative of deliberate consumption of inflorescences (Bryant 1974a:413), either solely or in conjunction with other edible parts of the plant as in a soup or stew. Aggregates of globemallow (Sphaeralcea sp.), corn, Cheno-ams (members of the Chenopodiasceae, or goosefoot family, and the genus Amaranthus, or pigweed), beeweed (Cleome sp.), sunflower, and grasses (Gramineae) were observed.

To evaluate the importance of a dietary item at a site, the frequency of occurrence and the dominance of a pollen type were noted (Scott 1979:266). Values for dominance were obtained by calculating a percentage from the number of times a taxon occurred as the dominant taxon in a group of samples. For example, corn pollen occurred in 11 out of 28 coprolite samples from Chaco Canyon, or 39% (Table 3).

The pollen of plant remains was sorted in four categories: (1) cultivated plants, (2) edible weedy plant species, (3) edible wild plant species, and (4) noneconomic plant species. Cultivated plants are those plants that were purposefully planted, tended, and harvested for food. Edible weedy plants are those that grow in disturbed areas such as cultivated fields and site vicinities. Like cultivars, they produce annual crops of flowers and seeds that may be edible and provide nutrients. They may have been semicultivated (Wier 1976:80). Edible wild plants are those plants that occur naturally and are used for food. Non-economic plant species are hose plant species that occur in low frequencies and do not appear to have been used either because they are not edible or were out of season. They occur as ambient, or incidental pollen.

The pollen record indicates that there are no apparent differences in diet between the samples from the two pueblos. The same major taxa are characterized by similar frequencies of occurrence. These are corn, Cheno-ams, low spine composites, beeweed, high spine composites (including wild sunflower), grasses, pinyon, squash, purslane, hackberrey (Celtis sp.), Mormon tea (Ephedra sp.) and globemallow. Other taxa are present in the sample from one pueblo only. At Pueblo Alto, gooseberry (Ribes sp.), sedge (cf. Carex sp.) and yucca (Yucca sp.) are present. At Pueblo Bonito buckwheat (Eriogonum sp.), two types of cactus, and a liliaceous (Lily Family) pollen type are present. Here frequencies of occurrence are low, with one exception (Type A Cactaceae occurs in 44% of Pueblo Bonito samples). Most of these latter species are naturally occurring, wild edible plants. Compared to cultivars they are not abundant in the floristic community; they grow in specific and sometimes restricted areas, and they produce few flowers and fruits. Though they may be harvested seasonally and stored, they would not be eaten as often.

The major dietary components are cultivars and weeds. Corn appears to have been most important in Chacoan diet and it occurs in all of the samples. In 39% of the samples it is the dominant taxon and comprises between 43% and 99%. The remaining samples contain between 0.9% and 33% corn pollen. Squash pollen was found in 39% of the samples. Squash flowers produce few but extremely large pollen grains and are insect-pollinated. It is suspected that the presence of squash is underrepresented since its pollination mode limits its possibility of ever occurring as a dominant in a sample. The pollen evidence from these samples suggests that squash was a frequent dietary item. Both the squash flower and fruit were consumed by prehistoric and historic Southwestern peoples (Whiting 1939:93).

Table 3. Percent frequency of occurrence and frequency of occurrence as dominants of select plant types in coprolites from three Anasazi locations.

	Chaco Canyon, N=28			Antelope House, N=39[a]			Hoy House, N=59[b]		
Taxon	% freq.	1st dominant pollen type	2nd dominant pollen type	% freq.	1st dominant pollen type	2nd dominant pollen type	% freq.	1st dominant pollen type	2nd dominant pollen type
Cheno-am	93	21	25	79	10	18	100	24	27
Grasses[c]	57	3	0	51	0	8	58	5	2
Pine	89	0	14	77	0	3	90	3	10
H.S. Composites	71	4	4	54	3	8	N/A[d]		
L.S. Composites	82	0	14	51	3	3	N/A		
Juniper	32	0	0	10	3	3	59	0	5
Corn	100	39	14	72	13	5	95	5	7
Squash	39	0	7	36	0	10	41	7	0
Beeweed	68	14	11	90	56	10	95	39	15
Mallow	14	4	0	0	0	0	7	0	0
Opuntia	4	0	0	26	0	8	14	0	0
Purslane	29	4	4	13	3	3	27	2	0
Mormon Tea	21	0	4	8	0	0	20	0	0
Gooseberry	11	0	0	0	0	0	2	0	0

Table 3. (continued).

Taxon	Chaco Canyon, N=28 % freq.	Chaco Canyon 1st dominant pollen type	Chaco Canyon 2nd dominant pollen type	Antelope House, N=39[a] % freq.	Antelope House 1st dominant pollen type	Antelope House 2nd dominant pollen type	Hoy House, N=59[b] % freq.	Hoy House 1st dominant pollen type	Hoy House 2nd dominant pollen type
Hackberry	25	0	4	3	0	0	0	0	0
Sedge	4	0	0	0	0	0	0	0	0
Greasewood	46	4	0	8	0	0	17	0	0
Other		6	4		9	21[e]		15[f]	34[g]
Total percent		100	100		100	100		100	100

[a]Williams-Dean and Bryant 1975:98-99.

[b]Scott 1979:264-266.

[c]Ricegrass included.

[d]Not applicable.

[e]Cottonwood (*Populus* sp.), Cattail (*Typha* sp.) and unknown pollen types.

[f]Sage (*Artemisia* sp.)., cattail and umbell family (Umbelliferae).

[g]Sage, mint family (Labiatae) and taxa not accounted for.

Cheno-ams comprise a major plant type of edible weedy species. The pollen of Cheno-ams is difficult to separate morphologically with the light microscope. It occurs in 93% of the samples. Except under unusual conditions, Cheno-am pollen dominates the pollen record of soil samples from archaeological features in Chaco Canyon (Cully 1977:34-41). This abundance is the result of three factors: the pollen of these species resists decay, they are prolific producers of pollen, and the plants are abundant in the floristic community. In the coprolitic samples Cheno-ams are dominant in five. Their presence appears to be ethnobotanically, rather than environmentally, influenced since numerous aggregates of pollen were noted. The seeds and leaves of these species are nutritious and they were considered to be an important food for Southwestern peoples (Stevenson 1915: 66; Castetter and Underhill 1935: 23-24; Curtin 1949:47-48). Other than pigweed (Amaranthus), it is uncertain which species of Cheno-ams were utilized, since other macrobotanical remains of this taxon were not encountered (Toll 1981).

Globemallow was abundant in one sample and occurred in 15% of the samples. The root was used medicinally by the Hopi as well as by the Pima, Shoshone, and Picuris (Curtin 1949:80-81; Murphey 1959: 43; Krenetsky 1964:48; Whiting 1939:31). The mucilaginous stems of a species of mallow (Sphaeralcea angustifolia) were used for chewing gum by the Hopi (Castetter 1935:31).

Wild sunflower occurs in 54% of the samples, and in one sample it is the most abundant taxon. The pollen and macrobotanical evidence points to the consumption of the seed. The seeds were used for food and the roots were used medicinally by California Indians (Helzer and Elsasser 1980:246). In the 1930s, Whiting (1939:96-97) noted three species of wild sunflower in use on the Hopi reservation in Arizona. Helianthus seeds were eaten and the stalks were used for construction of the ventilation hood over the piki stone. The seeds produced a fine purple and black dye for basketry and textiles and were used in the preparation of ceremonial body paint.

Other members of the sunflower family (Compositae), besides Helianthus, are found in the samples. Forty-nine species of Compositae grow in Chaco Canyon, and many of them are ethnobotanically useful (Cully 1978). The composite pollen in the samples consists mainly of low spine composites, a term derived from a morphological feature, the short spine of the pollen grain. These species are difficult to separate morphologically. Low spine composites occur in 79% of the samples. Scott, in her study (1979) of the Hoy House coprolites, found no evidence that composites were an important dietary element. They do not exceed 12% in relative frequency and though they occur in 63% of the Hoy House samples, they are usually representative of one to two percent of the pollen (Scott 1979:268). In the Chaco coprolites they occur in a higher overall frequency and are the dominant taxon in three. This suggests they were consumed as a food item by Chacoans.

Beeweed appears to have been a major food item. It is a weedy plant that grows in disturbed areas and along roadsides during the summer months. It does not appear to be generally abundant in the plant community, although Judd (1954: 86) notes that it flourished on the flooded areas near Fajada Butte. The coprolite evidence indicates that it was frequently consumed, especially with corn. It occurs in 68% of the samples and is the dominant taxon in four. In the study of coprolites from Hoy House, Scott found that beeweed was a dominant pollen type in more than half of the samples (Scott 1979:269), indicating that it was a major dietary item there as well. The seeds (Stiger 1977:82) and most likely the greens were eaten. Scott notes that the greens are far more palatable before flowering. Large quantities of leaves were gathered and hung indoors for winter use among the Zuni, where they were cooked with boiled corn and highly seasoned with chile (Stevenson 1915:69). Among the Tewa large quantities of young plants were collected in July, then boiled. The resulting paste was made into cakes, which were used for food and also as a black paint base (Robbins and others 1916:59). Whiting notes that beeweed, growing in the cornfields at Hopi, was a managed crop (1939:18,77-78). Martin and Sharrock comment on the abundance of beeweed in Anasazi coprolites and suggest that it follow corn, beans, and squash as one of the leading foodstuffs in the diet of prehistoric people in the Four Corners areas (Martin and Sharrock 1964:176-177).

Purslane (Portulaca sp.) is found in 26% of the samples and is the dominant taxon in one. Five species of purslane, a salt-tolerant succulent with small flowers, are native to New Mexico (Martin and Hutchins 1980:682). Southwestern people dried large quantities of purslane by spreading the young stems out in the sun on roofs; the dried stems could be boiled and reconstituted as a potherb. The seeds germinate following summer rains and the young growth would be available continuously up to late fall (Harrington 1967:87-89).

Many of the edible wild plants are found in the canyon today; grasses, Mormon tea, yucca, prickly pear, gooseberry, and sedge (Cully 1978). Hackberry can be found in nearby areas. Grasses occur in over half of the samples and are the dominant taxon in one. The grass types in the coprolites compare favorably to Indian ricegrass and dropseed. Of all the grasses present in the San Juan Basin, ricegrass was a most important food resource. The Hopi collected the large, black seeds in quantity (Whiting 1939:18,65). The Navajo, Paiute, and other Indian groups from Zuni westward to southern California considered it an important food resource (Castetter 1935:27-28; Elmore 1944:26; Murphey 1959:27). The Hopi used five species of dropseed for food (Whiting 1939:18,66).

Pinyon pollen occurs in many of the samples but never in abundance. Since the nut was the food item (Toll 1981), quantities of pinyon pollen would not be expected.

Hackberry occurs in one-fifth of the samples and is present in moderate amounts in two. The berries were eaten by the Navajo; Rio Grande Pueblo Indians, the Acoma and Laguna; and the Papago (Castetter 1935:21; Elmore 1944:41).

Gooseberry pollen was present in 11% of the samples. One sample contains a substantial amount of this pollen, indicating fruit consumption. Three species grow in the canyon today (Cully 1978), and were probably available for consumption in the prehistoric times as well.

Comparison With Other Late Anasazi Sites

Results from the analysis of coprolites from Hoy House (Scott 1979) and Antelope House (Williams-Dean and Bryant 1975) were compared to the results from Chaco Canyon. Hoy House is a large Pueblo III cliff dwelling with at least 60 rooms and 4 kivas located at the head of a small, narrow, unnamed tributary of Johnson Canyon on the Mountain Ute Indian Reservation in southwestern Colorado (Scott 1979:257). It lies approximately 125 km north of Chaco Canyon. Antelope House, a Pueblo II-III site, is located in Canyon de Chelly, Arizona, approximately 150 km southwest of Chaco Canyon. Excavation of the pueblo revealed at least 89 rooms with 5 large kivas (Rock 1975:4-5).

Because results of the pollen analyses from the three sites were methodologically similar, they were used for comparison. Frequencies of occurrence and dominance of a taxon were calculated for the pollen types that were present as a means of detecting similarites and differences in diet. Table 3 shows the percent frequency of occurrence of each taxon and the dominants (first and second) at each of the sites.

The dominants from each of the three sites are Cheno-ams, corn, and beeweed. In frequency of occurrence Cheno-ams rank very highly and are second in dominants at each site. Corn also has a very high frequency of occurrence: 100% at Chaco, 72% at Antelope House, and 95% at Hoy House. This indicates that corn was consistently available for consumption. It comprises 39% of the first dominants at Chaco, 13% of the first dominants at Antelope House, and 5% of the first dominants at Hoy House. Dominants in the Chaco samples indicates that corn was regularly eaten. At the other two sites corn appears as a first dominant in lesser percentages suggesting that, at least in these sets of samples, it was not consumed as regularly.

The representation of beeweed is notable considering its status as a semicultivated weed. It is most lightly represented in Chaco Canyon with a frequency of 68%. At Antelope House and Hoy House it is present in 90% and 95% of the samples, respectively. It is the most dominant pollen type at Antelope House and Hoy House and the third most dominant taxon at Chaco. Together, the above three taxa comprise the majority of the pollen found in the coprolites (Table 4).

Squash occurs in similar frequencies at all three sites and is a dominant

Table 4. Percentages of plant taxa as dominant pollen types.

Taxon	Chaco Canyon	Antelope House	Hoy House
Cheno-ams	21	10	24
Corn	39	13	5
Beeweed	14	56	39
% of Total	74	79	68

pollen type in 7% of the Hoy House coprolites, indicating that it, too, was available and perhaps consistently utilized. It is difficult to evaluate the role of the sunflower family since different criteria were used at Hoy House for the description of the Compositae. Similarities of occurrence are noted with the Chaco and Antelope House samples and it appears that the Compositae were consumed with some regularity as well. Grasses appear in over half the samples from each site and appear as first dominant taxon in small percentages at Chaco and Hoy House. They were probably not consumed as frequently as the cultivars but were still a sought after food item.

The faunal data from Chaco suggest the regular, indiscriminate consumption of the body parts of small mammals and birds. Comparison of the mammal data with the other sites is less precise due to varying sampling techniques for bones, but small mammals are found in Hoy House coprolites (Stiger 1977), suggesting similar consumption habits.

Summary

An analysis of food remains from coprolites from Chaco Canyon yielded descriptive information useful in defining some dietary habits of Classic Period Chacoan people. Small mammals were a frequent part of the diet. Consumers seem to have had little preference for body parts since all body parts were represented in samples. Some of the bone appears to have been cooked, some does not.

The evaluation of macrobotanical and pollen remains indicates that Chaco inhabitants made use primarily of cultivars and edible weeds. They also consumed the fruits, nuts, and inflorescences of wild plants when available. It seems likely that the diet was an omnivorous one, where nutrients were obtained in a number of ways by using a variety of strategies.

A comparison of the pollen of coprolite samples from Chaco with coprolites of two other Anasazi sites of similar size and time period illustrates much similarity in the use of plants for food. All contain the same major taxa. Similarities in the representation of minor taxa are present as well. From the analysis it would appear that the basic subsistence of these Anasazi agriculturalists does not differ to an appreciable extent. Constrained by the limits imposed upon them, be they environmental, cultural, or a combination of many factors, it can be seen that these people were responding in remarkably similar ways.

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