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SPATIAL ANALYSIS OF ARCHAEOLOGICAL DATA AT THE JOHN MARTIN DAM AND RESERVOIR, SOUTHEASTERN COLORADO

by

Frank W. Eddy, Richard E. Oberlin, and T. Reid Farmer

ABSTRACT

Prehistoric spatial data recovered from the John Martin Dam and Reservoir, Bent County, southeastern Colorado, was obtained from sites of the Archaic, Formative, and Buffalo Hunter stages of High Plains archaeology. These data, most of which dates to the last 3000 years, were analyzed in order to address four problem areas: (1) site function, (2) site-to-site networking, (3) past adaptive practices, and (4) evolutionary trends in the data. These problem domains were examined using such cluster and correlation statistics as: (1) an original Nearest Neighbor (NN) routine, (2) Z-coordinate cluster mapping, and (3) two computer program packages called NTSYS and SPSS.

The NN investigation into site function led to the conclusion that the scatters of lithic artifacts do contain distributional information. Some 80% of the 99 analyzed prehistoric sites were found to contain internal clustering. Comparison of these internal artifact clusters led to the conclusion that the largest majority are duplicates. In general, it can be said that the John Martin lithic scatter sites exhibit a very low degree of internal organizational complexity and a very high repetition of internal artifact patterning.

At the intersite level of functional analysis, NTSYS classification revealed seven site types of which five are special activity sites and two are base camps. Use of the NN statistic showed that the small, upland special activity sites clustered in four groups along the north side of the Arkansas River whereas the large, bottomland base camps clustered in a single group favoring the south side of the river. These differences are explainable as a long-term, stable community in which the Arkansas was crossed twice annually from winter-time base camps to summer-time special activity camps and back again.

By correlating cultural and environmental variables to the site types through the use of the SPSS programs, it was found that the special activity sites: (1) contained tools for processing vegetal and game resources, (2) were core reduction stations, and (3) were involved in upland hunting. In contrast, the adaptive practices inferred for the base camps consist of the functionally defined tasks of: (1) milling of large-seeded grasses, (2) manufacture and repair of implements, and (3) hunting of riparian game.

The evolutionary research question was examined from the general proposition that functionally defined site types will express adaptive change over time as a response to a changing natural environment. An NTSYS analysis of just those 11 datable sites shows a marked correspondence between artifact content and temporal age. This finding led to the conclusion that cultural evolution proceeds by changing patterns of adaptation.

INTRODUCTION

The John Martin Dam and Reservoir Project was a multi-phase site survey investigation into the cultural resources located along the Arkansas River just below the confluence with a major tributary stream, the Purgatoire River (Fig. 1). The project was conducted by a private firm, Science Applications, Inc. (SAI), of Boulder, Colorado, under contract with the Corps of Engineers, Albuquerque District. The mission of the project was to locate, describe, evaluate, and conduct scientific inquiry into both the prehistoric and historic properties encountered. However, for purposes of this paper, we will consider only the prehistoric data and its distributional analysis leaving the historic remains and management goals for other presentations (Eddy et al. 1982).

The research theme of the project was to perform distributional analysis of the prehistoric site survey data in order to learn about: (1) site function, (2) site-to-site net-

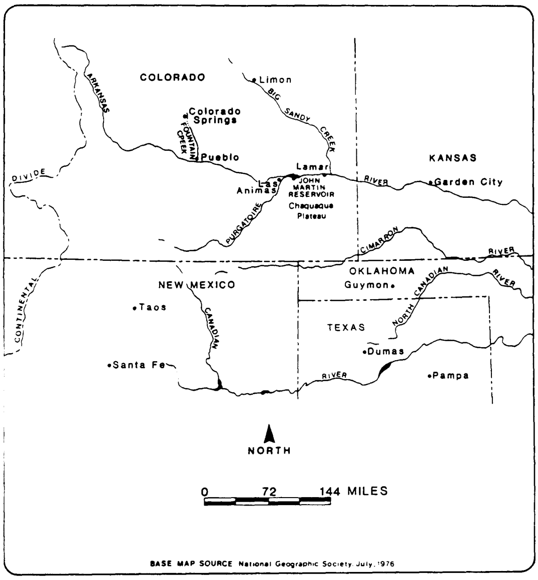


Fig. 1. Regional map showing the location of the John Martin Reservoir Project.

working, (3) past adaptive practices, and (4) evolutionary trends (Eddy et al. 1980). This article will focus on the techniques of spatial analysis which were employed to realize these four research objectives.

The John Martin Dam and Reservoir is an existing flood control and recreational facility located on the Arkansas River in Bent County, southeastern Colorado. It is positioned about halfway between the towns of Las Animas and Lamar, 58 miles west of the Kansas/Colorado border and approximately 100 miles east of Pueblo, Colorado, and the foothills of the Colorado Front Range (Fig. 1). This location is part of the central portion of the High Plains, a section of the Great Plains Physiographic Province (Hunt 1967). The Great Plains are a vast, gently rolling to flat terrain drained by major rivers in the west, such as the Arkansas, which have their headwaters in the Rocky Mountains. As one moves towards the mountains, there is a progressive decline of rainfall leading to more xeric, shortgrass prairie, a steppe type of semiarid vegetation such as found in the vicinity of the John Martin Project. At an elevation of 3870 feet, the project area averages just over 12 inches of rainfall annually to form a hot, dry, semiarid climate. The seasonal range of precipitation indicates a somewhat wetter summer and a dry winter.

Although the contract stipulated survey coverage of some 40 square miles of fee and easement lands, the areas covered by the existing lake, silt, and marsh reduced the actual surface available for inspection to 24.2 square miles. And, in fact, the actual exposed land surface changed somewhat from day-to-day as reservoir waters were released for downstream farm irrigation during the summer field season of 1980. Of the data obtained, natural transformations (N-transforms) affecting intrasite artifact patterning were most serious along the rising and falling lake perimeter as the wave action dislocated individual artifacts to create randomness (Ascher 1968; Schiffer 1976). However, these distorted distributional data were identified and removed from consideration by a unique form of spatial analysis called Z-coordinate cluster mapping. About 20% of the sites so analyzed exhibited a randomness of artifact distributions, most of which can be attributed to disturbance by wave action. A second possibility for N-transform disturbance has to do with aeolian blow-out affecting sites situated upon vegetation-stabilized dune fields located along the south bank of the river. However, it should be pointed out that these internally disturbed sites are still useful for intersite study. The bulk of the sites recorded, furthermore, are situated on geologically old land surfaces which have been stable for many thousands of years. The intrasite conclusions to be presented are based on the remaining 80% of the prehistoric data which did show internal patterning, largely in the form of artifact clustering due to culture transformations (C-transforms) (Schiffer 1976).

Basically C-transforms are tendencies in the distribution of artifactual and site data leading to structure brought about by patterning inherent in human behavior. This patterning, which is expressed in living societies by the scheduling of institutionalized activities in time and space, in turn leads to discernable patterning in the archaeological record expressed as artifact clustering. But upon formation of the archaeological site, this patterning is systematically randomnized over time by such agencies as natural weathering, biological decay, and cultural modifications of the landscape. Ascher (1968:44) describes culture as negative entropy, that is a build up of organization, energy, and information, whereas archaeological site formation is a process of entropy, that is a running down of information, energy, and organization. Thus C- and N-transforms are forces opposed to one another although both are operating simultaneously on living society and the resulting archaeological record.

Collection of data was made by three, three-person crews which made pedestrian coverage of the survey area lying between the fluctuating lake perimeter and the right-of-way boundary. Site recording was conducted following a modified, no-pickup policy in which the largest part of the data was field identified and left in place to minimize the archaeological impact on each site. However, in those few instances where time-diagnostic artifacts, such as projectile points and pottery, were encountered, these were collected for laboratory study and curation. By these means, 133 archaeological sites were located and recorded. Of these, 111 prehistoric components and 34 historic components were defined. Twelve sites were classified as double component properties, exhibiting both prehistoric and historic remains. Ninety-nine prehistoric components were actually encoded to form a data file suitable for computer analysis. Sites such as rock art and unique remains were not deemed suitable for the distributional study which had a settlement theme.

The first phase of the project was literature search and the writing of a research design, steps which were formulated in a Planning Document (Eddy et al. 1980). This background statement was essential in order to plan the research procedures, both field and laboratory, as well as systemize the field recording typology. Without this preliminary step, it was feared that much among-crew error would be introduced into the data file from lack of agreement in artifact classification, a serious concern with any "no pick-up" survey. Results of the cultural and environmental background study for southeastern Colorado are summarized in Figures 2 and 3.

As shown in Figure 2, we had expected upwards of 12,000 years of prehistory to be presented along the Arkansas ranging from the Paleo-Indian Clovis hunters of mammoth to nineteenth-century equestrian bison hunters. In fact, the stylistic dating of projectile points and pottery did not verify that either chronological extreme was present. Instead, the actual local sequence extended from the early Archaic through the Plains Apache of the eighteenth century. In addition, one tipi ring site could represent one of the tribal groups known from the eighteenth and nineteenth centuries: Cheyenne, Arapaho, Ute, Comanche, or Kiowa, all of whom have been ethnohistorically identified as residing at one time or another along the upper Arkansas (Eddy et al. 1982). Although only 11 sites could be assigned to a temporal period, most of these are datable to the late Archaic and post-Archaic times, suggesting that the bulk of the occupation covers only the last 3000 years (Table 1). Uncertainty in the dating of sites was introduced by the practice of local residents who have scavenged specimens for years building large collections of projectile points and pottery. This assessment is important to our treatment of the modern environmental variables and the prehistoric sites. Since the majority of the sites are thought to date to the Late Holocene epoch, a geological interval during which a minimum amount of environmental change was experienced, it seems reasonable to project modern environmental variables into the past. However, should it be found that any significant number of archaeological sites do in fact date to earlier times, then such an extrapolation could not be justified (Fig. 3). The present study assumes little major climatic change between the present and the identified prehistoric past. This assumption is justified by the fact that climatic reconstructions for the last 5000 years are basically like the climate of today with just minor degrees of variability expressed by Wendland (1978) who uses such labels as Sub-Boreal, Sub-Atlantic, Scandic, Neo-Atlantic, Pacific, Neo-Boreal, and Recent (Fig. 3).

Table 1. List of Dated Prehistoric Sites.

Period 1, early Archaic: 5BN232,245

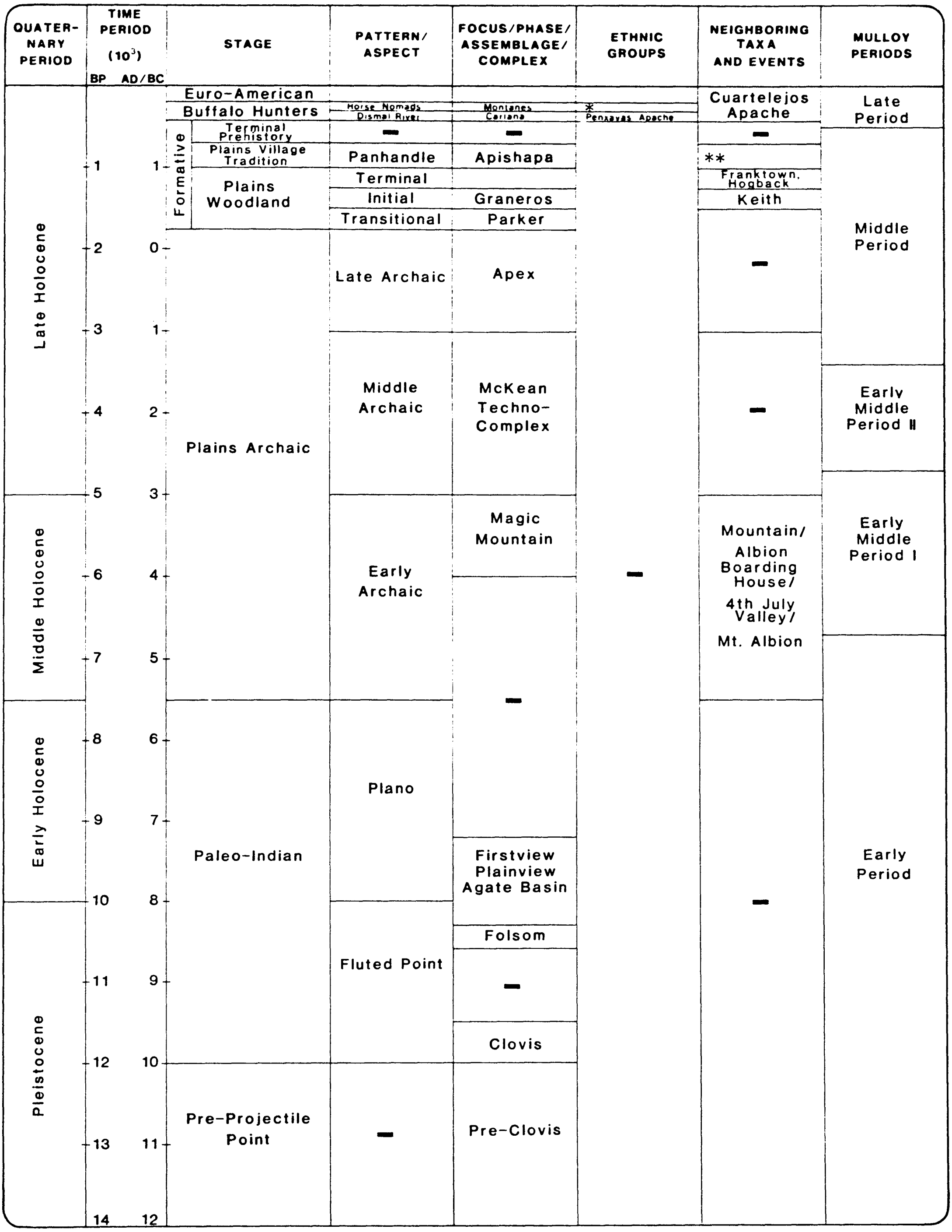
Period 2, early through middle Archaic: 5BN186

Period 3, middle Archaic through Plains Woodland: 5BN254

Period 4, late Archaic through Plains Woodland: 5BN176

Period 5a, Woodland through Dismal River: 5BN170 (pottery), 254

Period 5b, post-Woodland: 5BN169 (point, pottery), 176,187,122,248 5BN252 (pottery)



* Cheyenne/Arapaho/Ute/Comanche/Kiowa
** Sopris/Optima/Antelope Creek/Upper Republican

Fig. 2. Cultural chronology for southeastern Colorado.

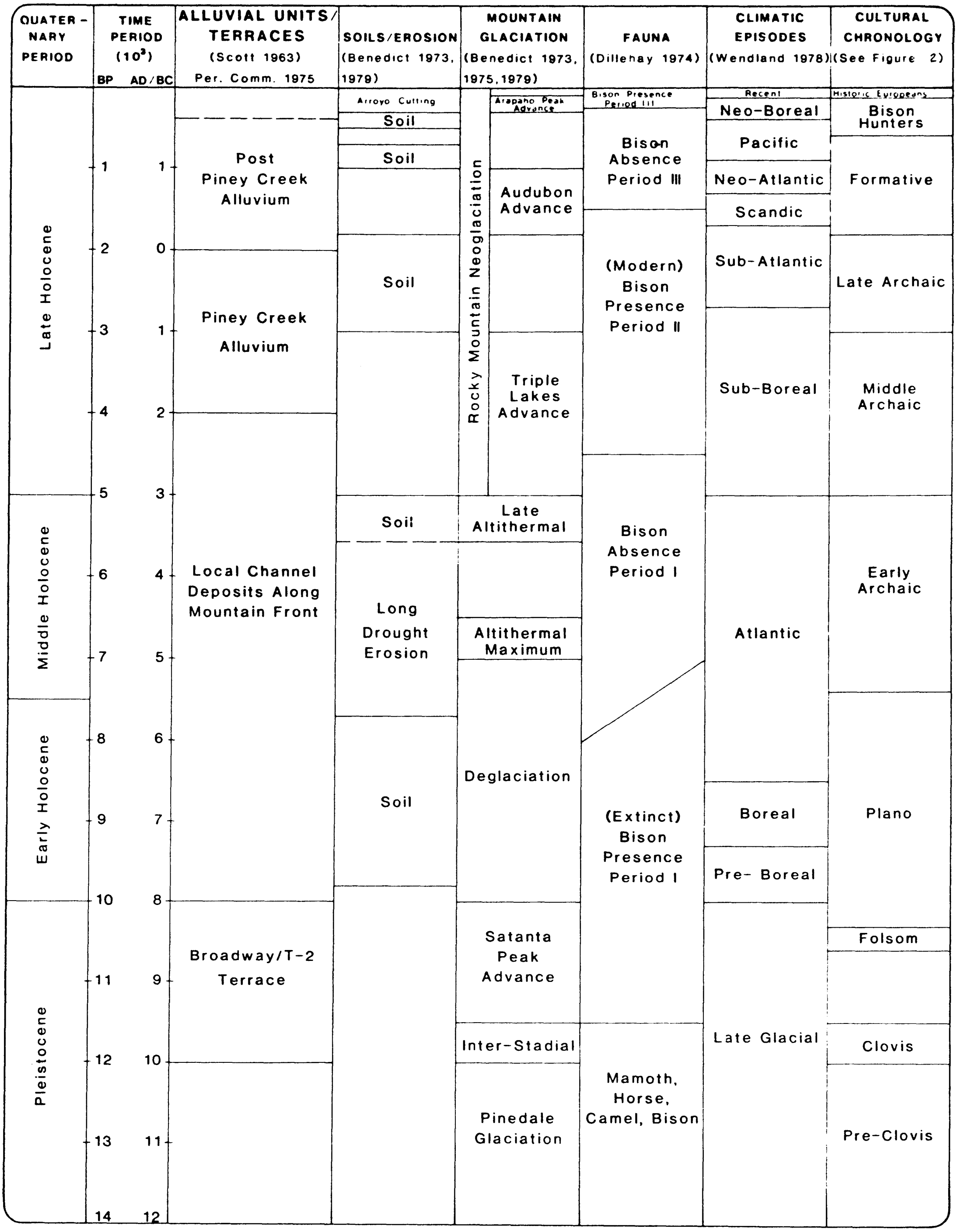


Fig. 3. Environmental chronology for southeastern Colorado.

RESEARCH METHODS

The research orientation for the prehistoric sites led to piece plotting of individual artifacts for purposes of studying intrasite and intersite variability. The data were organized as 59 quantified observations so that the theoretical models and hypotheses posed in the research design could be tested through computer and statistical treatment. Manipulation of the voluminous data file was facilitated through a commerical contract between SAI and the University of Colorado for the use of a CDC Cyber 172 computer.

Field Procedures

The common class of archaeological sites encountered on the John Martin survey was a scatter of lithic artifacts without evidence of a midden matrix. These lithic scatters were found in the open as well as occasionally under bedrock overhangs. Other rare classes of artifacts found on sites were potsherds, fire hearths, scattered hearthstones (burned rock), and/or dry laid masonry walls. Still other sites consist of rock art of pecked or incised drawings executed on the cliff face of a sandstone outcrop. One cache of exotic stone tools (alibates and obsidian) was found hidden under a boulder.

In general, the common lithic scatter site is widely distributed throughout Colorado. This site type constitutes a research enigma since it is so difficult to extract behavioral information from the seemingly haphazard spread of artifacts. The usual practice is to make guesses as to site function with little or no systematic evaluation of the site constituents. This practice continues today among professionals despite the common practice of piece plotting artifact data and the construction of scattergram maps. It remains nearly universal that such distributional data are almost never analyzed by any objective means. It was for this reason that the John Martin Project endeavored to extract distributional patterns as a means of testing whether there is indeed meaningful cultural information present in the provenience data. If not, then the continued scattergram mapping of lithic scatters would seem a waste of time, money, and effort. On the other hand, if distributional information is present, then not only should piece plotting continue as a routine field procedure, but the spatial data so obtained should be analyzed for its functional implications. Next, patterned changes through time can be investigated seeking evolutionary regularities.

In the field, a crew, upon discovery of a lithic scatter hidden within the short-grass prairie cover, would deploy a search pattern. As each artifact was encountered, its position was marked by an engineer's pin flag in order to define a scatter of specimens. The flutter of flags defined the site configuration, the perimeter of which outlined the site extent. To facilitate spatial analysis, the actual recording of artifact data was conducted in blocks so that between-specimen distances could be obtained for Nearest Neighbor (NN) analysis, the base statistic for cluster mapping. Block recording was conducted according to two rules. That is, small lithic scatter sites of 100 specimens or less were completely recorded as a census whereas large sites in excess of this figure were sample-recorded. The actual piece plotting of specimens was accomplished using a tripod-mounted Brunton pocket compass and steel tape. By this means, each specimen was provided with provenience measurements consisting of an azimuth heading and distance in meters recorded from a site datum. These two spatial coordinates, then, became the data input for computer mapping. In addition to the location coordinates, each artifact was identified to one of 22 conventional use categories, examples of which are: scraper, knife, projectile point, biface, or waste flake type (Eddy et al. 1982). In addition, lithic material identification was recorded to form four classes of observations for each specimen.

At the time that piece plotting was underway one crew member prepared a scattergram map consisting of point location with field specimen number assigned to each data record. This roughly done map provided a check on the computer mapping which was executed later in the laboratory. These computer maps formed the data base for the intrasite functional study.

Laboratory Data Analysis

The purpose of data analysis was to define the nature of the intrasite and intersite spatial variability using the 59 data observations for each site. These observations consisted of quantified environmental and cultural variables. The former were taken from the USGS topographic maps and from the Soil Conservation Service (SCS), Range Site classification for Bent County. The variables recorded from the topographic map included such measures as distance to water, elevation, slope, aspect, and others. The Range Site classification provided data on the natural habitat near each archaeological site. A Range Site is a mappable unit expressing a combination of factors to include soil type, major and minor vegetation, ordinal preference (high, medium, or low) of native wildlife, and standing crop productivity. The Range Site constituents are so designed as to express potential rather than present field conditions and thus remove the effects of European impact on the landscape. Seven Range Sites are found in and around the Reservoir and these were coded as nominal (discrete) observations using the SCS code of Preator (1971). In addition, continuous measures were made between a site and the Range Site boundary as well as counts of Range Sites within a 1- and 3-km circle as a measure of environmental diversity.

In constrast to these environmental measures were a series of cultural variables. These observations included frequency of artifacts per site and such site attributes as size in square meters, artifact density, total number of artifacts, artifact type count, Universal Transverse Mercator (UTM), coordinates, and others. In this study, the UTM coordinates are employed as data for the intersite analysis using the NN statistic in order to define significant site clusters reflecting former prehistoric communities.

Distributional analysis of the cultural resources was primarily based on techniques of cluster analysis. Clustering was performed in two kinds of space: (1) two-dimensional geographical space, and (2) the space of classification. The latter has been called hyperspace by the systematic biologists (Sokal and Sneath 1963). Hyperspace can be defined as the degree of formal relatedness among artifact variables. Unlike the two-dimensional space of geography, hyperspace is made up of many formal scales by which artifact variability is measured. These include both discrete and continuous variables employed in morphological classification to effect both typologies and taxonomies. Clustering in geographical space was accomplished using the NN statistic developed by Clark and Evans (1954), while clustering in hyperspace was performed by means of the various statistics of Numerical Taxonomy developed by Sokal and Sneath (1963) and applied to archaeological data by Johnson (1968) and others (Clarke 1968).

Archaeological applications of the NN statistic involve the isolation of patterns of artifact distribution, such as clusters, which may then be used in conjunction with various other analytical techniques to identify prehistoric activity areas. The NN statistic compares an expected mean distance to the observed (measured) distance from a given point to its nearest neighboring points. The ratio of the expected to observed distance is called an R-statistic with values scaling from less than 1.0 (clustering of points), through 1.0 (random), to greater than 1.0 (even or perfectly ordered).

Of concern in any NN study is the "boundary effect," that is, the fact that the outermost members of any spatial distribution may in fact be closer to unobserved points outside of the study area than they are to recorded points within the study area (Clark and Evans 1954). The usual practice is to drop those recorded points which are closer to the boundary of the study than they are to interior members of the distribution. However, in the John Martin study the intrasite artifact analysis did not pose a "boundary problem." This was because each site was recorded as a scatter of artifacts in which the site boundary did not have any artifact members beyond its perimeter. In this manner we negated the "boundary effect" at the intrasite level of analysis. However, the intersite analysis did present us with a boundary problem: how to address the border of the lake and the Corps of Engineer property limits, and still retain enough sites for the purpose of clustering site types. The traditional solution to this problem was impractical for reasons apparent from viewing the study area map: we would have to eliminate most of the sites from the analysis.

Since we were interested in cluster aggregates of functionally similar site types classified by the Numerical Taxonomy

System of Multivariate Statistical Programs (NTSYS), we defined point clusters of sites using the NN program and then color coded each site by morphological type within each spatial grouping. This procedure resulted in our ability to define aggregates of site types based on the dominate site type occurring within each point cluster. Dominance here refers to the most common site type within that cluster. More than 70% of the sites sorted themselves discretely into spatial clusters so that the four site aggregates lying north of the river were largely made up of Site Types 1 through 5 while Site Types 6 and 7 lay almost entirely along Rule Creek and on the south side of the Arkansas. This dominance of objectively defined functional site types within each NN point cluster lends strong support to the conclusion that we have in fact identified real aggregates.

Other support for the belief that the border effect did not introduce significant bias within the intersite analysis is found in the nth order approach. Since there is statistically significant deviation towards clustering in the intersite analysis at the neighbor levels r_1 to r_4 ($p < 0.01$), we feel maintenance of internal clustering to the fourth level supports the conclusion that these are actual clusters of sites rather than statistically contrived aggregations (Eddy et al. 1982:222).

Finally, in order to reduce the error usually associated with inflated area values (i.e., deflated density), the total study area employed in the intersite study was reduced by approximately 63% in the NN calculations (Eddy et al. 1982:220). By this manipulation, we have taken the possible error to the conservative side, thereby lending support to our conclusion that we have in fact defined real aggregates of functionally similar site types and not artificially induced clusters.

It is a common practice of geographers to employ this R-statistic to characterize an entire population of points. However, in the John Martin investigation, we attempted to increase the recovery of intrasite spatial information by calculating NN for each point and contouring the resulting values, a move designed to map actual artifact clusters in order to render a graphic picture of the activity structure of that site. This cluster mapping procedure was based on a measure called the Z-coordinate (Z_c) cluster technique developed by David Larson (1980) to expand the capabilities of the nth order NN analysis. The results are a graphic or visual representation of the distributional patterns based on deviations of an artifact distribution from a random pattern. The technique is based on the ratio of the mean observed distance of neighbor level ($\bar{r}_{o_i}$) to the actual distance from each artifact to its ith NN.

In a distribution, if $R < 1.0$, a tendency towards clustering is mathematically defined. In order to determine the amount of clustering, Larson developed the Z_c scores, where r_{o_i} is the measured distance from a point to its ith nearest neighbor:

$$Z_c = \sum_{i=1}^{10} (\bar{r}_{o_i}/r_{o_i})$$

The ratio $\bar{r}_{o_i}/r_{o_i}$ gives a numerical value by which a relative weighting factor may be assigned to each artifact (point) within the distribution. Consider for instance, that the measured distance from a point to its nth NN is less than the mean observed distance ($\bar{r}_{o_i}$). Then by definition, the ratio of $\bar{r}_{o_i}/r_{o_i}$ will be greater than 1.0. By the same logic, if the measured distance is greater than the mean observed distance, the ratio will be less than 1.0. If a point has many close neighbors, the summation of the ratio (Z_c) will produce a relatively large number. Conversely, if a point has few close neighbors, the Z_c will be a smaller number. Further, if the measured distance is approximately equal to the mean observed distance, the Z_c will approximate 1.0.

This allows an assignment of a larger weight to points with many close neighbors, and a relatively smaller weight to points with few close neighbors. The result, then, is that clusters of artifacts will have high Z_c scores and isolated points will have small Z_c scores.

In developing and using the Z_c technique, Larson (1980) and Oberlin (1980) were interested in a computer-generated visual representation of the Z_c. The Z_c cluster map was suggested by Larson as a way of representing clusters in a two-dimensional x, y grid system. The technique is quite simple and allows a visualization of the clusters that is readily apparent (Fig. 4).

Larson saw that in a two-dimensional map, various geometric figures could be used in the

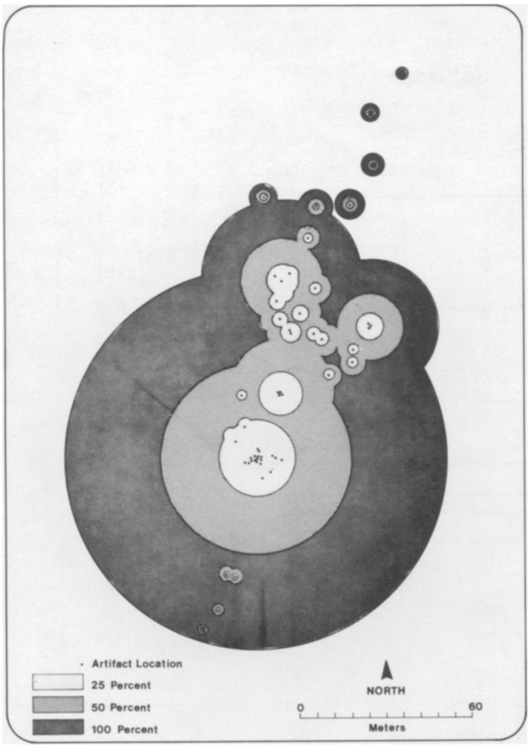


Fig. 4. Scattergram map of 5BN140.

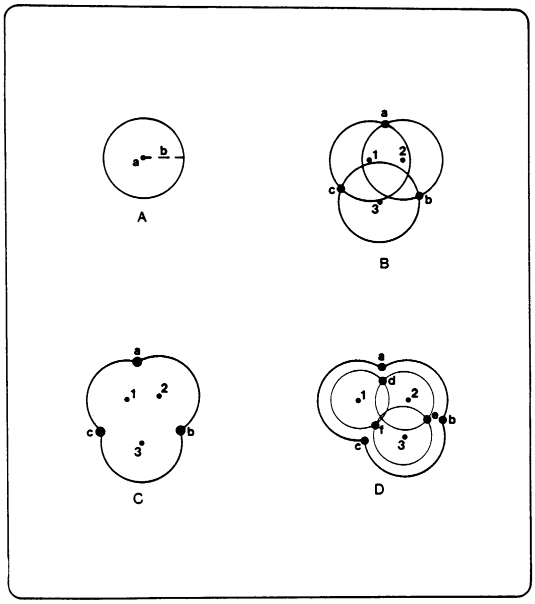


Fig. 5. Diagrams showing steps in Z-coordinate mapping.

second dimension to represent the Z_c. After experimenting with various shapes, he chose the circle as the simplest, both from a mathematical and visual viewpoint. The technique is outlined as follows.

The Z_c value for a point in the distribution is used as the radius of a circle, the scale being equal to the grid scale. A circle is then drawn around this point, with the point as the center (Fig. 5A). This is repeated for every point in the distribution, producing numerous overlapping circles (Fig. 5B). Next, the points of overlap at the outer edge of all circles are used as the first level of clustering (Fig. 5C).

The Z_c values are then consistently factored by a chosen arbitrary value. The values selected for the John Martin Project are 1.0, 0.5, 0.25, producing three levels of clusters: 100%, 50%, and 25%. It should be noted that the Z_c score is a relative weighting factor and that Z_c level one need not be 100%. In fact, as long as consistency is maintained for all Z_c levels, any value may be used to factor. This allows flexibility in producing the maps.

The second level of clustering is produced as 0.5 (Z_c) for all Z_c's in the distribution. This factored score is then used as a radius for the second level (Fig. 5D). Again, only the outer segments of the circle are retained. This procedure is repeated using 0.25 (Z_c) for the third level. This factoring may be carried out until individual points are isolated at the final level. Figure 4 is an example of the final Z_c cluster maps produced for the project.

The potential usefulness of isolating individual points may be seen if the researcher is interested in visualizing specific point patterns in the distribution. In analyzing a large site, with a plethora of artifacts and/or structural remains, each group of artifact and/or structural types may be color coded at the innermost Z_c level. This would allow the researcher to visually determine activity areas, house foundations, and so forth, by simply looking at the resultant Z_c cluster map.

Clustering of artifact clusters and sites in hyperspace was performed by the Numerical Taxonomic program called Numerical Taxonomy System of Multivariate Statistical Programs (NTSYS). We selected an average-link clustering rule to compare artifact clusters and sites using a similarity coefficient. Attributes compared consist of the 22 artifact type frequencies. The resulting coefficients are arranged in a similarity matrix where they

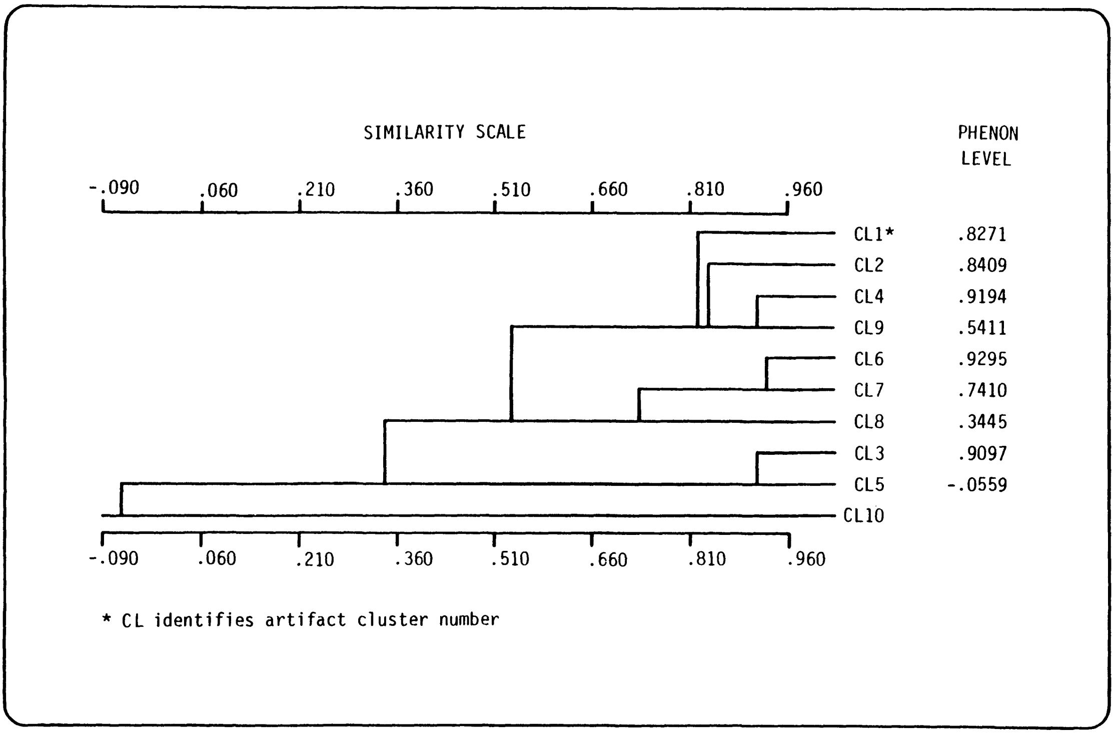


Fig. 6. NTSYS dendrogram of 5BN221 showing intrasite artifact clusters.

are sorted so as to place most similar cases adjacent to one another, a procedure like that used in chronological seriation (Johnson 1968). A graphical output of such a classification is illustrated by a tree-diagram called a dendrogram. Figure 6 shows such a comparison for artifact clusters within John Martin (5BN221) Site 96, while Figure 7 shows the use of the NTSYS to build a functional classification of sites. These two dendograms respectively illustrate cluster analysis in hyperspace at the intrasite and intersite level.

A final approach to data analysis was the application of Version 8, Statistical Package for the Social Sciences (SPSS). This package of programs was employed to run both univariate and bivariate statistics on the 59 variables in order to define their frequency distributions as well as relate pairs of variables through the use of association and correlation statistics. As a rule, we tended to stay away from the use of the SPSS multivariate statistics such as Factor Analysis due to the severe criticisms which are currently being directed towards these sophisticated analytical techniques (Thomas 1980). One exception to this rule, however, was our use of Regression Analysis for purposes of predictive modeling of site location, a management stipulation in our Corps of Engineer's contract.

PROJECT CONCLUSIONS

The findings from these various ap-

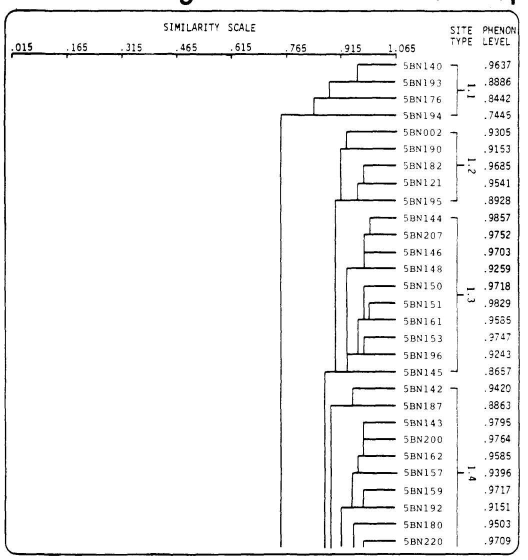


Fig. 7. Dendrogram of site types. Only part of Type 1 is shown to illustrate the form of the NTSYS output.

proaches to spatial analysis are presented below in terms of the four goals of the project. These categories are an inquiry into: (1) site function, (2) site-to-site networking, (3) past adaptive practices, and (4) evolutionary trends.

Site Function

The research question of site function was based on a proposition which states that the different kinds of artifacts and their numerical frequencies reflect the variety of task/activities conducted at that site. Statistics used to test this generalization against the John Martin data base include: (1) the NN statistic, (2) bivariate analysis, and (3) the NTSYS program package.

At the intrasite level of analysis, it was found that slightly more than 80% of the sites do exhibit internal clustering at the first nearest neighbor level (R-statistic is significantly below 1.0 with alpha less than .05), indicating a very high degree of patterning and information content. Within this group, 15% of the sites reflect two clusters while the remaining 85% contain anywhere from 3 to 10 clusters (Fig. 6). Further, a comparison of the internal artifact clusters using the NTSYS measure reveals that the largest proportion (90%) of these clusters express high similarity, meaning duplicate content, as opposed to the remaining 10% of the internally clustered sites which display the presence of dissimilar artifact cluster content, usually no more than two different artifact sets. The large number of sites expressing internal artifact cluster duplicates strongly supports the hypothesis of seasonal and periodic return to the same location (up to 10 times). Such a spatial pattern suggests that prehistoric peoples were doing the same things at the same place year-after-year. In contrast is the more minor spatial patterning expressed by intrasite artifact cluster differences interpretable as work task specialized areas or temporal reoccupation. Of the two alternative hypotheses, reoccupation seems much more likely despite our general inability to test this hypothesis given the paucity of datable artifacts. We can generalize by saying that the John Martin prehistoric sites exhibit a very low degree of internal organizational complexity and a very high degree of repetition of internal artifact patterning. The corollary to this proposition is that these ancient peoples were little specialized in their task/activity structure with everybody within the prehistoric band doing about the same thing at the same place, a reasonable fit with our usual expectations for an Archaic lifeway (Willey and Phillips 1958).

Shifting to the intersite level of analysis, NTSYS classification of sites by artifact content reveals seven functional types broadly interpretable as: special activity sites (Types 1-5) and base camps (Types 6 and 7). Table 2 lists the numbered variables (VAR #) which load high on the two major classes of sites as determined by bivariate analysis. It was found that the small size special activity sites were occupied seasonally for the exploitation of particular resources such as game (antelope, jack rabbits, and upland game birds), terrace lithics, and vegetable products. These special activity camps were positioned on the upland prairie north of the Arkansas River near intermittent tributary drainages and the conjunction of many SCS Range Site habitats.

In contrast, the base camps are large in size and located near the river bottomland on the south side of the Arkansas. They provided evidence of primary tool manufacture, tool maintenance, and repair activities. Base camps are located toward the center of SCS Range sites of high standing crop productivity. Milling tools were a common associate of base camps, strongly suggesting the processing of large-seeded grasses which favor the nearby dune fields.

Site Networking

Analysis of site-to-site relationships was based on a proposition which states that the various kinds of sites will be differentially arranged on the landscape to define a network of seasonal activities reflecting the organizational complexity of the prehistoric community. The research procedure to get at the question of intersite clustering was NN analysis using the UTM coordinates for each site.

Figure 8 shows the site clusters plotted on a reservoir map with hypothesized linking of base camps and special activity sites. The latter form four separate clusters on the upland

Table 2. List of Variables Defining the Two Site Types Comprising the Bivariate Scattergram Model.

BASE CAMPS

VAR12: Site Elevation (low)
VAR13: Distance to Nearest Intermittent Drainage (high)
VAR15: Distance to Arkansas (small)
VAR16: Height Above Arkansas (low)
VAR17: Distance to Edge of Range Site (high)
VAR18: Percentage of Dominant Range Site (large)
VAR19: Number of Range Sites in a One Kilometer Circle (low)
VAR20: Standing Crop Yield (high)
VAR31: Number of Hearths (high)
VAR33: Site Size (large)
VAR34: Artifact Diversity (maximum number of types)
VAR39: Hammer Percentage (high)
VAR47: Metate Percentage (high)
VAR48: Mano Percentage (high)
VAR52: Tertiary Flake Percentage (high)
VAR58: Unclassified Ground Stone Tool Percentage (high)

SPECIAL-ACTIVITY SITES

VAR12: Site Elevation (high)
VAR13: Distance to Nearest Intermittent Drainage (low)
VAR15: Distance to Arkansas (great)
VAR16: Height Above Arkansas (high)
VAR17: Distance to Edge of Range Site (low)
VAR18: Percentage of Dominant Range Site (low)
VAR19: Number of Range Sites in a One Kilometer Circle (high)
VAR36: Site Density in One Kilometer Circle (high)
VAR37: Site Density in Three Kilometer Circle (high)
VAR38: Chopper Percentage (high)
VAR40: Scraper Percentage (high)
VAR41: Biface Percentage (high)
VAR42: Projectile Point Percentage (high)
VAR45: Utilized Flake Percentage (high)
VAR49: Core Percentage (high)
VAR50: Primary Flake Percentage (high)
VAR51: Secondary Flake Percentage (high)
VAR56: Miscellaneous Core Tool Percentage (high)

prairie along the north bank of the Arkansas while the base camps form a single cluster positioned on the south side of the river, mostly along Rule Creek. These differences are explained as a settlement networking in which the Arkansas was crossed twice annually from winter-time base camps to summertime special activity camps and back again. The seasonal interpretation is admittedly weak since there are no excavated ecofactual data which can be brought to bear on this subject. However, certain evidence can be cited in support of seasons of occupation. For instance, the base camps favor the sheltered river bottom land where nonparametric rank order correlation statistics, such as Spearman and Kendall's Tau, demonstrate the association of bison, cottontail, elk, deer, and water fowl, the rank ordered variables being taken from the SCS Range Site classification. Bison particularly favor the riparian bottomland during the winter for shelter and forage, suggesting wintertime occupancy for the base camps. Further, the high percentage of milling tools (metates and manos) on these same sites indicates processing of grass seeds which would be most available in the fall; hence a fall and winter seasonality seems most likely. Again, the upland special activity sites are largely exposed hunting camps for prairie game such as antelope. It is our belief that these special activity camps were deployed in the spring and summer.

Adaptive Practices

The study of adaptation or the fit of a cultural pattern to its natural environmental setting has in part been described in the discussion above. Some further discussion on this subject will be presented in this section to amplify the picture of site type and community adaptation in the John Martin Reservoir area.

Adaptive practices at John Martin were investigated by working from a general proposition which states that different kinds of functionally defined site types will be located within different natural habitats (SCS Range Site Classification) according to resource needs. The research procedure employed was to link environmental and cultural variables to the seven numbered site types by means of the various bivariate statistics of SPSS as shown in part in Table 2. The special activity sites (Types 1-5) exhibit attributes interpreted as the following functional activity sets: (1) tools for processing vegetal and game resources, (2) gathering and first step reduction of lithic resources, and (3) upland

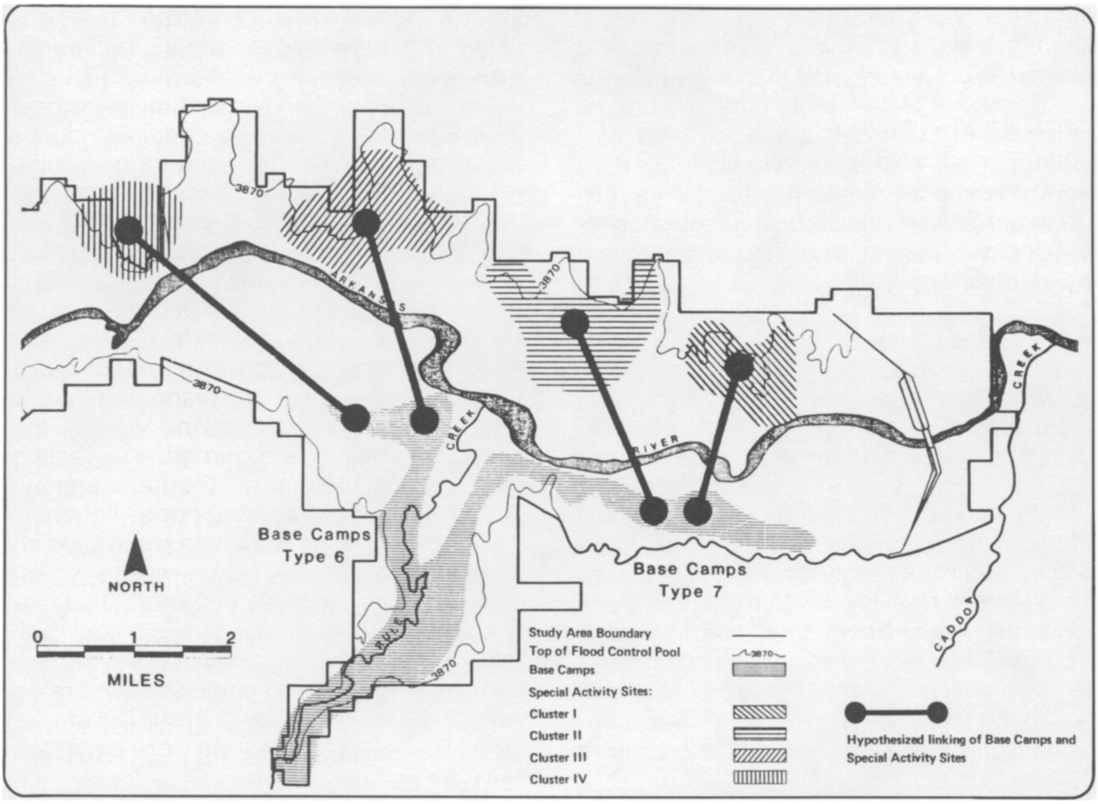


Fig. 8. Settlement modeling of the intersite clusters.

hunting. The hunting pattern has already been presented while the other two activity inferences are discussed here. Evidence that the upland fly camps are resource processing stations is taken from the range of shaped artifact types (VAR 38, 40, 41, 42, 45, and 56) listed in Table 2, while gathering and first step reduction of lithic resources is an interpretation drawn from the loading of Variables 49, 50, and 51 on these same sites (Table 2). These three variables are cores, primary flakes, and secondary flakes, respectively. The cores are nothing more than cobble knapping material collected directly underfoot from the high Pleistocene terraces (Eddy et al. 1982:Fig. 12.5). Particularly the Hasty gravels were exploited for suitable basalt and crypto-crystalline lithics. By opening these river rolled and cortex covered gravels, the prehistoric knapper had formed a core. One exploratory fracture revealed the suitability of the interior material, while several hammer breaks would have detached primary flakes with cortex-covered dorsal surfaces. Second generation removals from the core yielded secondary flakes. However, tertiary flakes (VAR 52) with no dorsal cortex avoided the special activity sites to favor the base camps as shown in Table 2. The significance of this negative correlation between Variable 52 and special activity sites will be discussed in a moment.

The activity structure associated with base camps, Site Types 6 and 7, consists of sets of functionally defined tasks to include: (1) milling of large-seeded grasses, (2) manufacture and repair of implements, and (3) hunting of riparian game. The evidence for the milling and river-side hunting has already been presented under site networking. Activity (2)—manufacture and repair of implements—is predicated on the high loading of Tertiary Flake percentages (VAR 52) on base camps rather than special activity sites (Table 2). The statistical avoidance of Variable 52 with cores, primary flakes, and secondary flakes (VAR 49, 50, and 51) is taken to mean that tool blanks were roughed-out at the fly camps, located on the high terrace materials source, and then returned to base camps where they were converted into finished tools. Although no systematic examination of tertiary flakes was made in the field due to the limitations of laboratory time and the unsuitability of such detailed work for a field setting, still it seems entirely likely that the tertiary flakes are a composite of manufacturing debris and rejuvination flakes left over from tool sharpening, that is manufacture and maintenance operations.

Evolutionary Trends

Unlike the three synchronic, functional questions covered above, the study of evolutionary regularities in prehistoric data requires diachronic time control. We attempted to deal with the lack of time control in the functional problems by collapsing all of the sites into a single, 3000 year-long time period, a procedure which was forced upon us by the temporal deficiencies in the data base. However, in order to address the evolutionary problem, we could not collapse but instead were forced to slim the useable data to just 11 sites containing some time sensitive artifacts as shown in Table 1.

The evolutionary proposition states that since the site types are functionally defined, then even slight changes in the natural environment over time will have generated adaptive changes in site content (Fig. 3). Corollary statements are that sites of the same time period will display high similarity with one another while sites of distinctly different time periods will express maximum difference in artifact frequency content.

The research procedure to address this evolutionary proposition was the employment of the NTSYS classification performed on the data by time period. In this fashion we could break out sets of archaeological sites by period to measure stability and change through time. It is predicted that sites of the same time period will show clustering at a high phenon (likeness) level while sites of differing adaptive and historical traditions will show somewhat different artifact content as expressed by cluster joining at a low phenon level.

At the time of the field investigations, stylistically distinctive pottery and projectile points were collected and dated by Reining (Eddy et al. 1982) These time-sensitive specimens were used to date 11 sites as listed in Table 1. Because the sites are surface exposures and could have been occupied many times, it was anticipated that each site in fact may be of several different ages. Further, the site dating seemed particularly risky since most sites produced only one time-sensitive specimen. However, despite these seeming drawbacks, an attempt was made to test the evolutionary hypothesis by running a dendrogram just on the 11 dated sites. The results were far more gratifying than could have been expected, as shown in Figure 9. Here, eight sites of the same time period are matched both in content and by time period. One site, 5BN186, is completely mismatched in that its tool content shows it to closely cluster with 5BN176 and 5BN187 while its dating is far removed (Chronological Period 2 versus Period 5b). In addition, sites 5BN232 and 5BN245 of early Archaic age showed little formal affiliation with any other sites, including each other, having phenon levels of 0.1115 and 0.3082 (Table 3). But in the aggregate, sites within this small sample do show a decided correspondence between formal content and temporal age, thereby providing support for the evolutionary proposition. Thus the idea that evolution proceeds by changing adaptive patterns is supported.

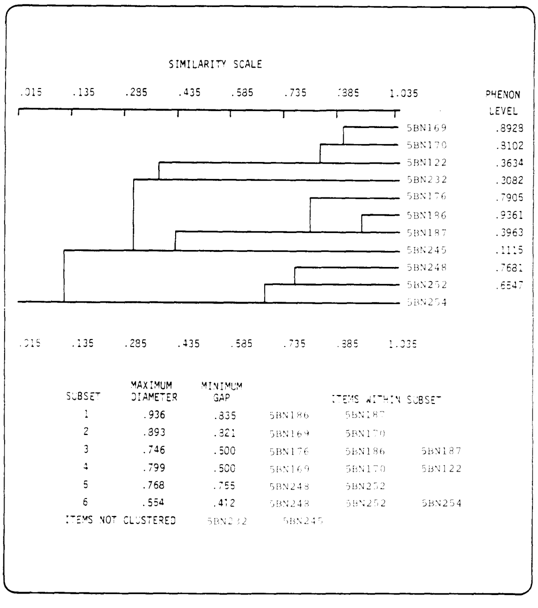


Fig. 9. **Dendrogram of dated archaeological sites used in testing the evolutionary proposition.**

Table 3. List of Dated Sites Employed in Testing the Evolutionary Proposition.

Site Number	Phenon Level	Chronological Period*	Match	Mismatch	Site Type
5BN167	.8928	5b	5BN170	——	5.2
5BN170	.8102	5a	5BN169	——	5.1
5BN122	.3634	5b	5BN169, 170	——	5.2
5BN232	.3082	1	——	——	1.4
5BN176	.7905	5b	5BN187	——	1.1
5BN186	.9361	2	——	5BN187	3.0
5BN187	.3963	5b	5BN176	——	1.4
5BN245	.1115	1	——	——	6.0
5BN248	.7681	5b	5BN252	——	6.2
5BN252	.6547	5b	5BN248	——	6.2
5BN254	——	3, 5a	5BN248, 252	——	7.2

*See Table 1.

SUMMARY

In review, we can confidently say that the ubiquitous and unpromising lithic scatter sites located at the John Martin Dam and Reservoir do contain distributional information. Further, although weaknesses are certainly present in the data, this information is sufficient to examine four research domains: (1) site function, (2) site-to-site networking, (3) past adaptive practices, and (4) evolutionary trends in the data. Furthermore, the spatial patterning elicited through the examination of these problem domains is explainable in cultural-ecological terms.

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REFERENCES CITED

Ascher, Robert
1968 Time's Arrow and the Archaeology of a Contemporary Community. In *Settlement Archaeology,* edited by K. C. Chang. National Press Books, Palo Alto.

Benedict, James B.
1973 Chronology of Cirque Glaciation, Colorado Front Range. *Journal of Quaternary Research* 3(4):584-599.

1975 Prehistoric Man and Climate: The View from Timberlain. In *Quaternary Studies,* edited by R. P. Suggate and M. M. Cresswell. The Royal Society of New Zealand, Wellington.

1979 Getting Away from It All: A Study of Man, Mountains and the Two Drought Altithermal. *Southwestern Lore,* Vol. XLV, No. 3. The Colorado Archaeological Society.

Clarke, David L.
1968 *Analytical Archaeology.* Methuan, London.

Clark, Philip J., and Francis C. Evens
1954 Distance to Nearest Neighbor as a Measure of Spatial Relationships in Population. *Ecology* 35:445-453.

Dillehay, T. D.
1974 Late Quaternary Bison Population Changes on the Southern Plains. *Plains Anthropologist* 19:180-196.

Eddy, Frank W., T. Reid Farmer, Leslie F. Lewis, Paul D. Friedman, Dennis L. Dahms, Dale L. Wedel, and Constance E. Farmer
1980 A Phase I Planning Document for the Culture Resource Survey of John Martin Reservoir, Colorado. Prepared by Science Applications, Inc. for submission to the Corps of Engineers, Albuquerque District, Boulder.

Eddy, Frank W., Paul D. Friedman, Richard E. Oberlin, T. Reid Farmer, Dennis L. Dahms, J. Jan Reining, and Beverly Leichtman
1982 The Cultural Resource Inventory of the John Martin Dam and Reservoir, Bent County, Colorado. Prepared by Science Applications, Inc., for submission to the Corps of Engineers, Albuquerque District, Golden.

Hunt, Charles B.
1967 *Physiography of the United States.* W. H. Freeman, San Francisco.

Johnson, LeRoy, Jr.
1968 *Item Seriation as an Aid for Elementary Scale and Cluster Analysis.* Bulletin No. 15, University of Oregon, Eugene.

Larson, David S.
1980 Further Possibilities for the Nearest Neighbor Test. Unpublished ms. University of Colorado, Boulder.

Oberlin, Richard E.
1980 *Spatial Analysis in the Interpretation of the Archaeological Record.* Unpublished ms. University of Colorado, Boulder.

Preator, Rodney E.
1971 *Soil Survey of Bent County, Colorado.* Soil Conservation Service, U.S. Department of Agriculture.

Schiffer, Michael B.
1976 *Behavioral Archaeology.* Academic Press, New York.

Scott, Glen R.
1963 Quaternary Geology and Geomorphic History of the Kassler Quadrangle, Colorado. *Geological Survey Professiona Paper* 421-A Washington, D.C.

Sokal, Robert R., and Peter H. A. Sneath
1963 *Principles of Numerical Taxonomy.* W. H. Freeman, San Francisco.

Thomas, David Hurst
1980 The Gruesome Truth about Statistics in Archaeology. *American Antiquity* 45:344-345.

Wendland, Wayne W.
1978 Holocene Man in North America: The Ecological Setting and Climatic Background. *Plains Anthropologist* 23:273-287.

Willey, Gordon R., and Phillip Phillips
1958 *Method and Theory in American Archaeology.* University of Chicago Press, Chicago.

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