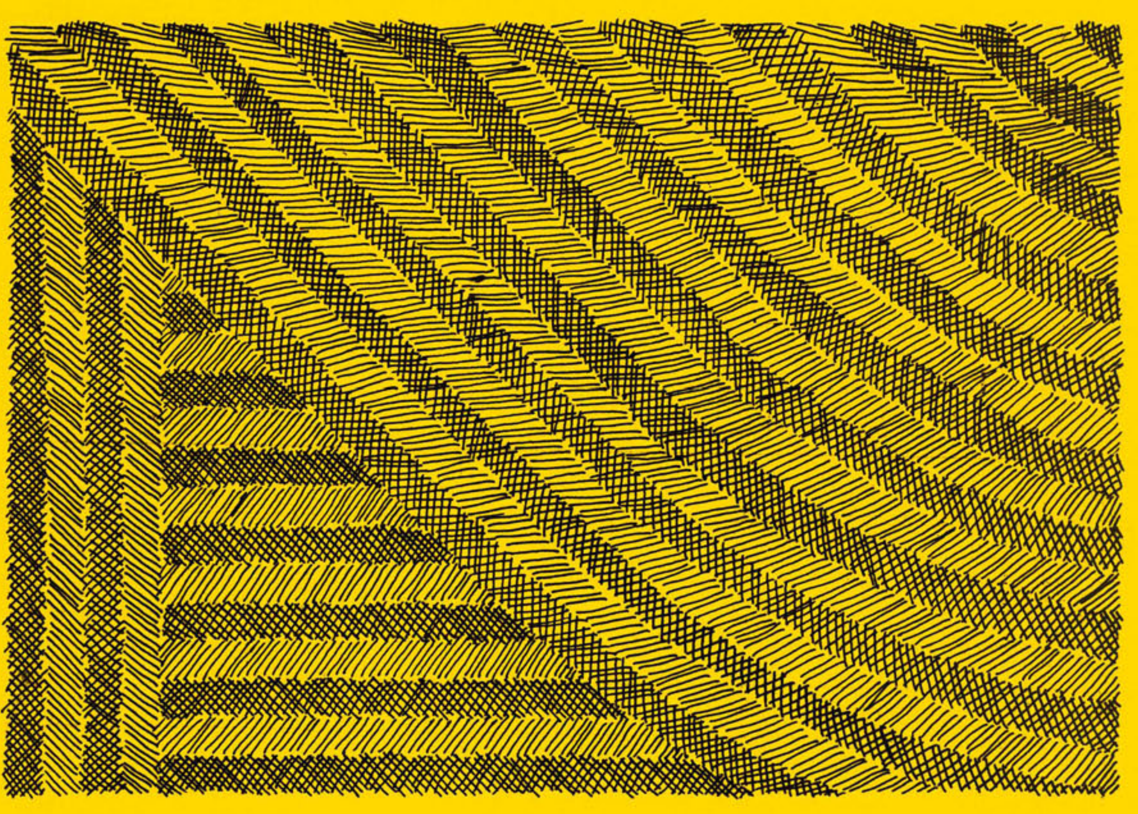
PLOWZONE ARCHEOLOGY: Contributions to Theory and Technique

Edited by Michael J. O'Brien and Dennis E. Lewarch



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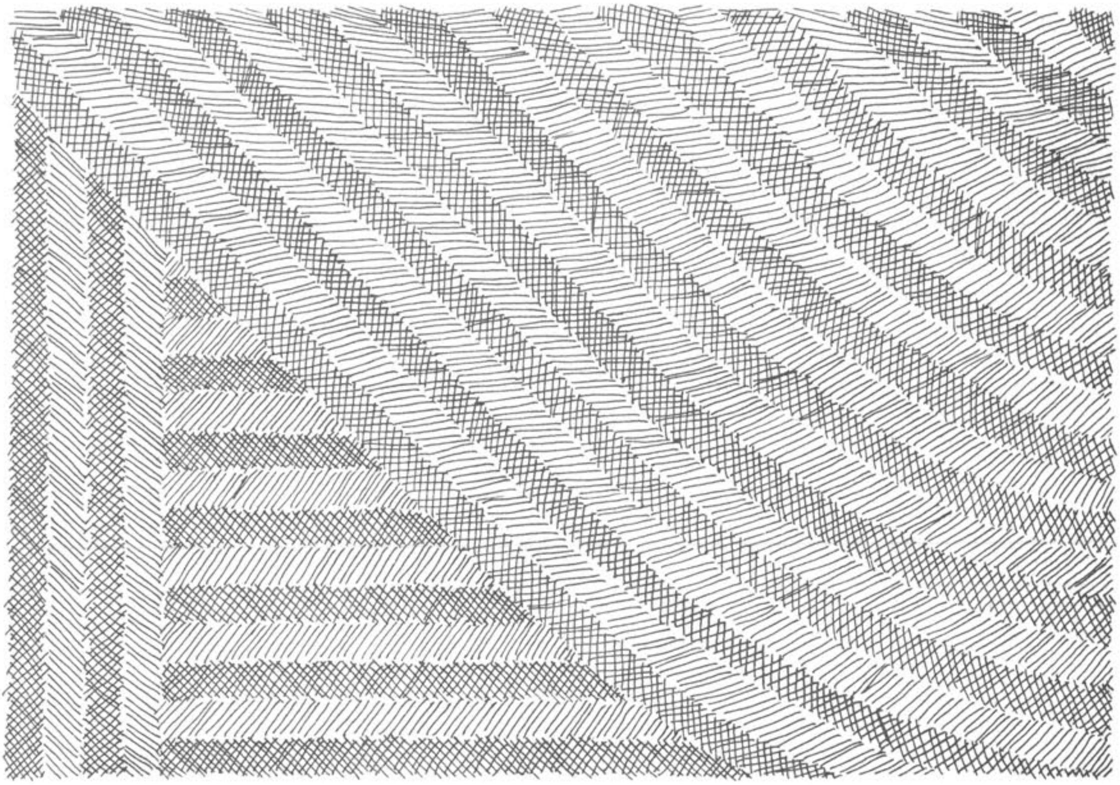

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INTRODUCTION

A number of observations concerning the use of plowzone material in archeology led to the inception of this volume. More archeologists than ever before are using plowzone artifacts for a wide variety of research topics. At the same time, there are few articles in the literature which deal specifically with appropriate field and analytical techniques, research potential, or limitations of plowzone archeology. Many recent treatments are difficult to obtain or are scattered throughout an array of national and regional journals, edited volumes, or cultural resource management series. Some discussions which would be of interest to a wider audience comprise a single chapter in a research or mitigation report. Based on this developing literature, there appears to be widespread interest throughout the discipline in plowzone archeology.

This observation has been further strengthened by discussions with colleagues at national and regional meetings. Apparently, a large number of archeologists have conducted informal observations on the effects of cultivation on archeological material in concert with surface collection field work. Most of these _ad hoc_ reviews have never appeared in print, even though they would be invaluable for development of a general model of tillage effects on archeological phenomena. Our observations were given even more reinforcement when Plog _et al_. (1978) identified plowzone archeology as an "analytical frontier" requiring extensive research.

Clearly, then, the time is right for a comprehensive treatment of the role of cultivation in the recovery of archeological materials. Within the limited scope of a single volume, we cannot hope to provide _the_ definitive review of the topic. However, by bringing together seven papers on a wide variety of tillage-related research, we hope to make a contribution toward more systematic treatment of plowzone archeological materials and to encourage other archeologists to share their insights into this important topic.

Based on our assessment of the current "state of the art" in plowzone archeology, we outlined a series of topics which needed coverage and contacted colleagues who were using plowzone materials in their research. Selection of contributions was guided by the following general goals of the volume:

1. to provide research results documenting effects of tillage operations on the distribution and recovery of artifacts in agricultural cultivation contexts;
2. to demonstrate a wide range of field and analytical techniques which appear useful for efficiently utilizing plowzone archeological phenomena;
3. to cover a wide range of geographical areas and levels of cultural complexity in order to demonstrate the broadest utility of plowzone artifacts;
4. to present a number of successful products using plowzone artifacts in order to demonstrate the research potential of this class of phenomena; and
5. to indicate the potential role of plowzone derived material for cultural resource management work.

Judging by the variety achieved in the following contributions, we feel the goals have been well met. Three papers describe changes in surface assemblages caused by variations in plowing practices, while a fourth describes relationships between surface and subsurface assemblages. A wide variety of data gathering and analytical techniques are utilized throughout the assembled papers. Geographical coverage includes projects in West Virginia, Kentucky, Alabama, Missouri, and Washington, with subsistence-settlement pattern systems ranging from generalized, mobile hunting and gathering groups to specialized, sedentary, nucleated societies. Five of the contributions generate useful products addressing a series of research problems dealing with internal structure of archeological settlements. Finally, five papers are the result of research requirements related to cultural resource management. We hope this "intellectual smorgasbord" will therefore have something to entice just about any archeologist.

We have attempted to arrange the papers in terms of their major emphases, moving from systematic descriptions of tillage induced changes in archeological material, to emphasis on field and analytical techniques, to papers summarizing research products which used plowzone materials. Many of the contributions, of course, cross-cut this simple arrangement by simultaneously touching upon a number of important research topics.

The initial contribution by Lewarch and O'Brien quantifies tillage induced changes in frequency and pattern of archeological surface materials under experimental conditions. Based on a review of archeological, agricultural engineering, and chemical engineering literature, they generate and test a series of propositions accounting for surface artifact distribution in the plowzone. Two identical sets of three artifact density patterns were subjected to different rates of disk plowing. By controlling for variability in soil, artifact size and material, equipment type, and surface collection technique, they are able to isolate changes in surface assemblages due exclusively to plowing. Comparison of pre- and post-tillage surface frequencies of three artifact size classes is used to evaluate recovery of initial population, change in relative proportions of each size class, and amount of pattern dispersion. They identify a number of factors contributing to structure of surface assemblages, including: direction and number of equipment passes; size, shape, artifact density, and structural complexity of pattern; and frequencies and relative proportions of different size classes of artifacts. They also indicate that tillage effects can be mitigated in pattern analysis by transforming artifact counts using a proportional weighting algorithm in the direction of equipment movement. Lewarch and O'Brien emphasize research results should be viewed with caution because of the short duration of the experiment. Nevertheless, their paper represents an important contribution in the direction of more precise quantification of tillage effects on archeological material.

The second paper, by Nance and Ball, is concerned with observing the effect of variation in collection unit size on sampling within a number of Archaic settlements in plowzone contexts along the Lower Cumberland River in western Kentucky. Using point provenience surface collection data converted to variable sized grid squares, they evaluate efficiency of cluster sampling procedures through assessment of the "design effect" statistic. Design effect is calculated for artifact classes from five sites of variable size and artifact density, grouping material by grid squares ranging from one to 12 m on a side. Based on scattergrams and principal components analysis, they note the design effect increases with grid size and that small grid units generally produce more consistent results than larger ones. They conclude by suggesting that small grid units are useful for estimating statistical precision as well as enhancing accuracy in data collection and fieldworker efficiency. Their generalizations are tempered by cautions about sample size and variation within classes of artifacts, but research results serve as informative guidelines for selecting provenience recording systems and analytical techniques for dealing with plowzone surface artifacts.

In the third paper, Jermann summarizes field and analytical techniques applied to low density artifact distributions comprising a site in the Lower Columbia River valley of southwestern Washington. Using exact provenience recording techniques, three systematic surface collections were carried out: one before plowing, one after plowing, and one after disking. Jermann notes variation in recovery rates of artifacts through consideration of such factors as artifact size, tillage treatment, soil matrix, and topography. He also evaluates utility of two statistical techniques for detection of pattern in artifact distributions: mean estimation nearest-neighbor and Morisita's Index of Aggregation, using point and quadrat provenience recording systems, respectively. When applied to combined collections of four major artifact classes, both indicate significant departures from random dispersion for three of four classes, with distributions tending toward clustering. Further analysis of internal settlement structure is carried out with a SYMAP plotting program to graphically display class frequencies in blocks of eight 2 x 2 m squares. Two kinds of low density clusters are defined: (1) fire-cracked rock and unmodified pebbles/cobbles occurring as large, spatially coherent patches throughout the site and (2) associations of tools and debitage in complementary distribution to fire-cracked rock clusters. Jermann's research demonstrates research potential of plowzone material through a well reasoned assessment of potential biases in the material and an extremely useful discussion summarizing the appropriateness of field and analytical techniques for definition of spatial pattern.

Contribution four, by Warren and Miskell, is a detailed quantitative analysis of surface collections spanning a number of time periods in a flood plain bottom locality along the Salt River of northeastern Missouri. All visible artifacts in a 43 ha plowed area were plotted using the point provenience recording technique. Visual assessment of artifact distribution defined twenty artifact clusters which served as the basis for quantitative investigation of technological and spatial variables. Warren and Miskell provide a carefully reasoned discussion of data requirements for the wide variety of statistical techniques employed throughout, with emphasis on the potential and limitations of plowzone surface materials. Referring to ecological models and a well documented summary of environmental data for the area, they generate and test a series of subsistence-settlement pattern hypotheses which account for settlement complexity and location. As a result, they define a settlement continuum ranging from relatively dense sites which reflect tool manufacture and maintenance to low density sites inferred to represent tool use, the former posited as residential sites and the latter inferred to represent procurement/processing sites. Residential settlement types appear to be reoccupied more frequently than special purpose settlements, consistent with expectations of the model. In summary, Warren and Miskell provide a synthesis of diachronic landuse in a single, environmentally diverse locality and are able to test a number of important hypotheses regarding adaptation in the Prairie Peninsula through careful analysis of plowzone derived surface artifacts.

Nance and Hurst in paper five consider a shallow, low density site in a plowzone context located on the flood plain of Locust Fork of the Warrior River in north-central Alabama. Contract work carried out within a sewerline right-of-way sampled the site with a stratified, random program of two-meter excavation squares. Horizontal and vertical distribution of lithic attributes are examined through contingency table and factor analysis. Several vertical and horizontal trends in flake and flake tool classes were documented. These trends, examined in conjunction with temporally diagnostic artifacts, led to definition of site structure, including the shifting size of occupation areas. They emphasize that in contract archeology, sites such as the O'Neal site are often dismissed as insignificant, even when eligible for contract funding. They suggest more attention be given similar shallow, plowzone sites.

Fuller's contribution, paper number six, uses plowzone surface materials to test hypotheses regarding development of small scale nucleated sedentary communities and their relationship to dispersed sedentary hamlets in the upland portion of northern West Virginia during a period between 500 B.C. and A.D. 1000. He provides tactical definitions of units such as community, village, and hamlet in order to test two hypotheses accounting for evolution of community patterns: the growth model and the nucleation model. The former posits development of functionally complex villages by gradual population accretion while the latter suggests villages result from a rapid reorganization of community pattern resulting in the nucleation of previously dispersed hamlets. Using SYMAP density contour maps to plot functional classes of ceramics and lithics, Fuller defines four settlement types varying in artifact density and functional complexity. Evaluating temporal and spatial relationships of these units, he determines that the nucleation model best accounts for community evolution in the study area and proceeds to synthesize evolution of community systems through time. While success of Fuller's work derives from application of controlled surface collection techniques to plowzone contexts, the major thrust of his paper is outlining and testing hypotheses of community pattern evolution. Nevertheless, his ability to tackle a complex research problem with plowzone artifacts clearly demonstrates the research potential of tillage modified archeological contexts.

We thank Patricia Petre and Pamela Warren for typing the manuscript and composing the tables, and Susan Vale who applied her drafting talents to produce figures which contribute greatly to the volume. We also thank William Autry for encouraging us to produce the volume and Judy Gorodetzky for ably editing the manuscript. To Ronald Spores we offer our sincere thanks for providing us the opportunity to publish the volume.

To the St. Louis District of the U.S. Army Corps of Engineers we owe a large debt of gratitude for providing partial funding for this volume. We would like to thank Terry Norris, Owen Dutt, and Jack Rasmussen of that office for their continued support of the Cannon Reservoir Human Ecology Project and for their sincere interest in assisting in the dissemination of results of the project. The papers by Lewarch and O'Brien and Warren and Miskell present results of work stemming from the Cannon Project.

M.J.O.
D.E.L.

EFFECT OF SHORT TERM TILLAGE ON AGGREGATE PROVENIENCE SURFACE PATTERN

by

Dennis E. Lewarch and Michael J. O'Brien

INTRODUCTION

Plowzone artifacts are currently being used in a wide variety of archeological research contexts, due in part to data requirements of regional analysis and cultural resource management. Despite the increased use of plowzone artifacts, most archeologists still poorly understand the effects of tillage on archeological materials. Tillage is defined as "the mechanical manipulation of soil for any purpose, but in agriculture the term is usually restricted to changing soil conditions for crop production" (American Society of Agricultural Engineers 1978:290).

In spite of many misconceptions about agricultural operations, some systematic observations of tillage effects have appeared in the archeological literature (Redman and Watson 1970; Ford and Rolingson 1972; Medford 1972; Roper 1976; Talmage and Chesler 1977; Trubowitz 1978; Ammerman and Feldman 1978). Although they are useful contributions to a developing literature on the subject, there are three major deficiencies in generally available studies: (1) post-hoc determination of artifact movement; (2) numerically small populations used in experimental studies; and (3) use of experimental materials which do not closely approximate the size and shape of artifacts comprising most archeological assemblages.

To contribute to what Plog *et al.* (1978:416) term "an analytical frontier", this paper presents results of a tillage experiment carried out in 1978 by the Cannon Reservoir Human Ecology Project. Three topics important for interpretation of pattern in surface assemblages are addressed: (1) factors conditioning population changes in portable artifact assemblages; (2) factors contributing to dispersion of artifact distributions; and (3) combined effects of dispersion and recovery on interpretation of artifact patterning.

DESCRIPTION OF THE EXPERIMENT

A controlled experiment was designed where equipment, artifact assemblage, artifact patterns, artifact population, rainfall, and surface collection techniques were held constant. Two variables were changed during the test trials: (1) number of passes made by tillage equipment and (2) direction of equipment movement.

A total of 6,160 chert artifacts formed three patterns which varied in size, shape, and density. Different counts of artifacts in three size grades were equally distributed on the ground within one meter squares (Fig. 1.1), with patterns created by combinations of squares. Pattern is thus measured by density across aggregate (grid square) provenience units rather than by point (exact) provenience, the latter being the technique used in most experiments reported to date. The choice was made because aggregate provenience is commonly employed in surface collection and is the most cost-efficient provenience recording technique for dealing with large populations of artifacts. Relative frequencies of each size grade (≥1",<1≥1/2",<1/2") referred to as 1", 1/2", and 1/4" objects) closely approximated those found in surface collections of lithic materials from sites in the Cannon Reservoir area of northeastern Missouri and appear to be fairly representative of lithic assemblages from other areas as well (Lewarch 1980). Artifacts used in the experiment were obtained from stripped plowzone of an archeological site in the Cannon Project area and are representative of typical shapes of cryptocrystalline artifacts in Cannon assemblages. Artifacts were size-sorted by screening material through one inch and one-half inch mesh.

Pattern 1 contained 2,130 artifacts arranged in the form of a high density concentration grading into lower density levels, then a break in artifact distribution, and then another fairly dense band of material (Fig. 1.2; Table 1.1). Two potential tillage effects were tested by using this pattern: (1) mixing of artifact density patterns across a boundary representing a break in pattern and (2) determining whether a naturally occurring density gradient can be distinguished from tillage induced gradients. Pattern 1 contained the largest population of artifacts, which allowed testing hypotheses regarding the role of large initial populations in recovery and pattern dispersion.

Pattern 2 was composed of 270 artifacts placed in six contiguous grid squares arranged in a 3 x 2 m block (Fig. 1.2; Table 1.1). This pattern approximates what have been reported in the archeological literature as "low density lithic clusters". Pattern compactness and uniform counts in all grid squares were designed to test pattern dispersion from a point source and the effect of a fairly small population on recovery rates and pattern definition.

Pattern 3 contained 500 artifacts arranged in a rectangular block surrounding an empty area (Fig. 1.2; Table 1.1), analogous

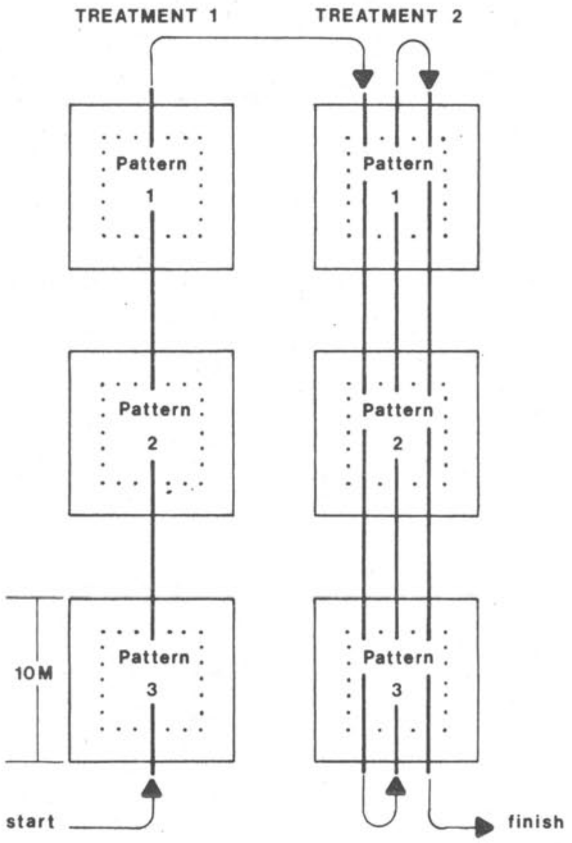


Figure 1.1 Plan of experiment.

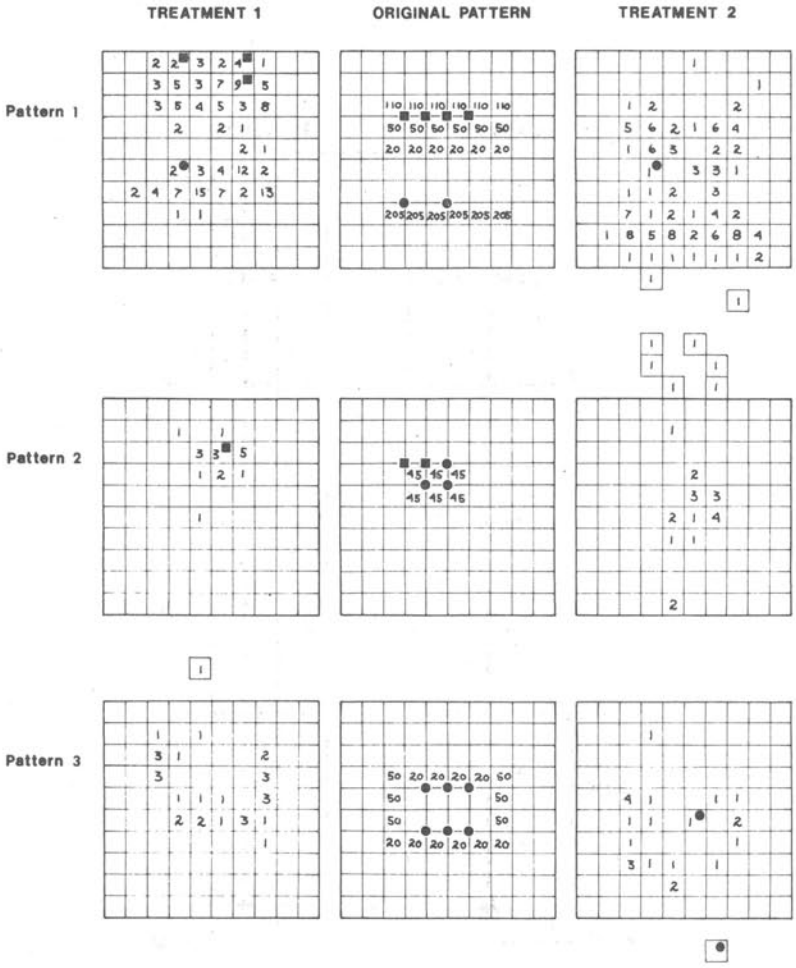


Figure 1.2. Total number of artifacts per grid unit by treatment. Shaded dots = projectile points; shaded blocks = cores.

		CONTROL PATTERN				TREATMENT 1								TREATMENT 2												
PATTERN	SIZE CLASS	N	% CON	MAX VER DIS	MAX HOR DIS	N	% CON	%T^1	% DIF % CON	MAX VER DIS	DIF CON	MAX HOR DIS	DIF CON	N	% CON	%T2	% DIF % CON	%T1	% DIF T1%	% DIF T1% CON	MAX VER DIS	DIF CON	DIF T1	MAX HOR DIS	DIF CON	DIF T1
1	TOTAL	2,310	100.00	6	6	158	6.84	100.00		8	2	7	1	135	5.84	100.00		85.44		- 1.00	16	10	+8	8	2	+1
	>1	90	3.90	6	6	20	22.22	12.65	+ 8.75	7	1	7	1	10	11.11	7.41	+ 3.51	50.00	- 5.24	-11.11	13	7	+6	7	1	0
	<1$\overline{>}$1/2	1,110	48.05	6	6	95	8.56	60.13	+12.08	8	2	7	1	74	6.67	54.81	+ 6.76	77.89	- 5.32	- 1.89	14	8	+6	8	2	+1
	$\overline{<}$1/2	1,110	48.05	6	6	43	3.87	27.22	-20.83	7	1	6	0	51	4.59	37.78	-10.27	118.60	+10.56	+ 0.72	16	10	+9	7	1	+1
2	TOTAL	270	100.00	2	3	18	6.67	100.00		5	3	4	1	20	7.41	100.00		111.11		+ 0.74	9	7	+4	3	0	-1
	>1	30	11.11	2	3	5	16.67	27.78	+16.67	5	3	3	0	5	16.67	25.00	+13.89	100.00	- 2.78	0.00	6	4	+1	2	-1	-1
	<1$\overline{>}$1/2	120	44.44	2	3	12	10.00	66.67	+22.23	3	1	4	1	9	7.50	45.00	+ 0.56	75.00	-21.67	- 2.50	5	3	0	3	0	-1
	$\overline{<}$1/2	120	44.44	2	3	1	0.83	5.56	-38.88	1	-1	1	-2	6	5.00	30.00	-14.44	600.00	+24.44	+ 4.17	3	1	+2	3	0	+2
3	TOTAL	500	100.00	4	6	31	6.20	100.00		9	5	6	0	23	4.60	100.00		74.19		- 1.20	8	4	-1	6	0	0
	>1																									
	<1$\overline{>}$1/2	220	44.00	4	6	19	8.66	61.29	+17.29	9	5	6	0	11	5.00	47.83	+ 3.83	57.89	-13.46	- 3.66	8	4	-1	6	0	0
	$\overline{<}$1/2	280	56.00	4	6	12	4.29	38.71	-17.29	4	0	6	0	12	4.29	52.17	- 3.83	100.00	+13.46	0.00	4	0	0	6	0	0

Table 1.1. Artifact Recovery by Pattern and Treatment.

to a plaza configuration or deposition of portable artifacts around the perimeter of a house. Variation in density levels and the empty central block provide another test of homogenation or smoothing of density values across naturally occurring gradients or breaks in pattern.

In addition to these patterns, six cores and 12 projectile points were placed at corners of some grid squares in order to measure movement and recovery of individual artifacts (Fig. 1.2; Table 1.2).

The patterns were contained in three blocks, each measuring 10 x 10 m, with a five meter buffer zone between blocks (Fig. 1.1). Duplicate sets of each pattern were created, one in each of two tillage corridors. Two tillage treatments were carried out: Treatment 1 (corridor 1) consisted of one pass in a northward direction of an 18-inch (45.72 cm) disk plow pulled by a diesel tractor at a working depth of nine inches (22.86 cm). Treatment 2 (corridor 2) consisted of the same equipment making three trips in the tillage corridor: a pass in a southward direction, followed by a pass in a northward direction, and a final southward pass. Following one inch of rainfall, the grid system was reinstated and standard intensive surface collection procedures were carried out within one meter squares. The experiment was conducted in a Putman series soil, which comprises roughly 10% of the Cannon project area. The Putman series is classified as poorly drained upland prairie soils. The upper nine inches (ca. 23 cm) of soil is a dark grayish brown silt loam with moderate to fine granular structure (Watson 1979:19); it contains no naturally occurring cryptocrystalline material. Results are presented in Figs. 1.2 through 1.5.

Before presenting and evaluating propositions concerning expected results of the experiment, some general observations can be made regarding inherent limitations in the experiment design. First, because material was placed on the ground surface and not covered by soil prior to disking, kinds and magnitude of some changes in artifact pattern will represent the maximum degree of tillage induced disturbance. Agricultural engineering research (Nartov 1979) has demonstrated that one-way disk plows have greatest displacement effects on materials located on the surface of the ground. Second, the short duration of tillage (three passes) tends to present extreme fluctuations of some factors, such as recovery rates of large objects. Tillage research has effectively demonstrated that equilibria occur in a number of processes after approximately 10 to 15 equipment passes (Kouwenhoven and Terpstra 1979). Increasing the duration of tillage beyond this point fails to produce further changes in such variables as particle segregation. With only three passes, general trends might be indicated but definitive results cannot be presented.

	CONTROL		TREATMENT 1				TREATMENT 2							COMBINED TREATMENTS		
CLASS	CONTROL POP	% OF CONTROL	N	%T1	%CON	%T1 DIF%CON	N	%T2	%CON	%T1	%DIF %T1%CON	%T2 %DIF%CON	%T1-%T2 CON	COM CON POP	N	%CON
TOTAL	3,080	100.00	207	100.00	6.72		178	100.00	5.78	85.99	-0.94			6,160	385	6.25
>1	120	3.90	25	12.08	20.83	+ 8.18	15	8.43	12.50	60.00	-8.33	+ 4.53	- 3.90	240	40	16.67
<1$\overline{>}$1/2	1,450	47.08	126	60.87	8.69	+13.79	94	52.81	6.48	74.60	-2.21	+ 5.78	- 8.06	2,900	220	7.59
$\overline{<}$1/2	1,510	49.03	56	27.05	3.71	-27.98	69	38.76	4.57	123.21	+0.86	-10.27	+11.71	3,020	125	4.14
CORES*	6		4		66.67		0	0.00	0.00	- 66.67				12	4	33.00
PROJ. POINTS**	12		1		8.33		2	16.67		+200.00				24	3	12.50
LARGE POP.	2,310		158		6.84		135	5.84		85.44	-1.00			4,620	293	6.34
SMALL POP.	770		49		6.36		43	5.58		87.76	-0.78			1,540	92	5.97

* Data from Table 1.1

** New information

Table 1.2. Recovery by Artifact Class, Population, and Treatment.*

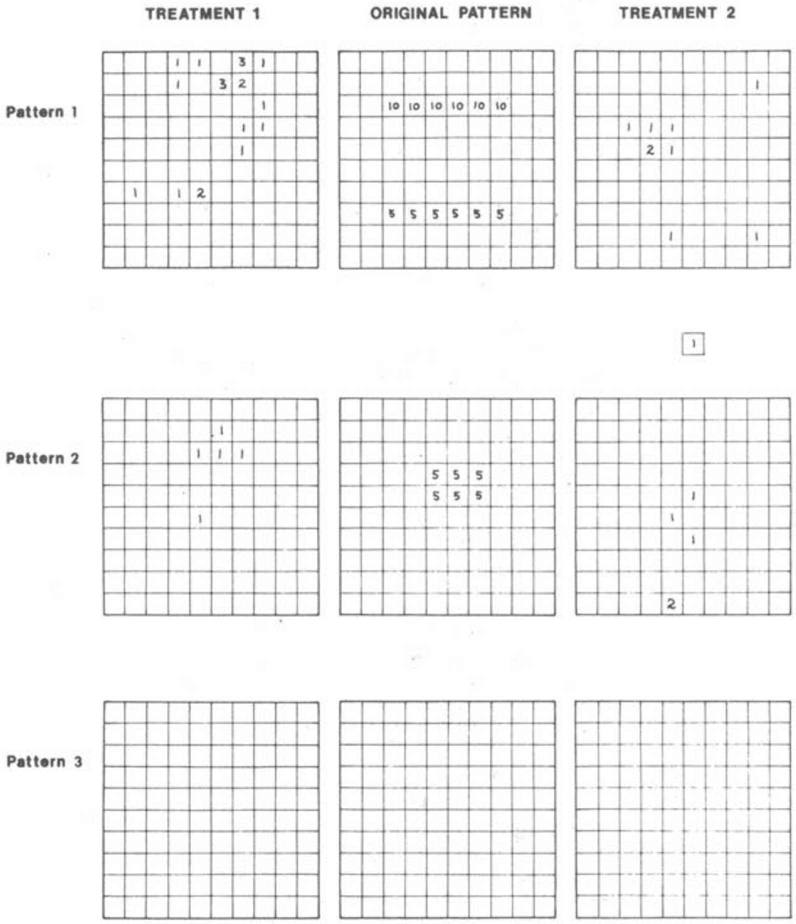


Figure 1.3. Number of ≥ 1 inch artifacts per grid square.

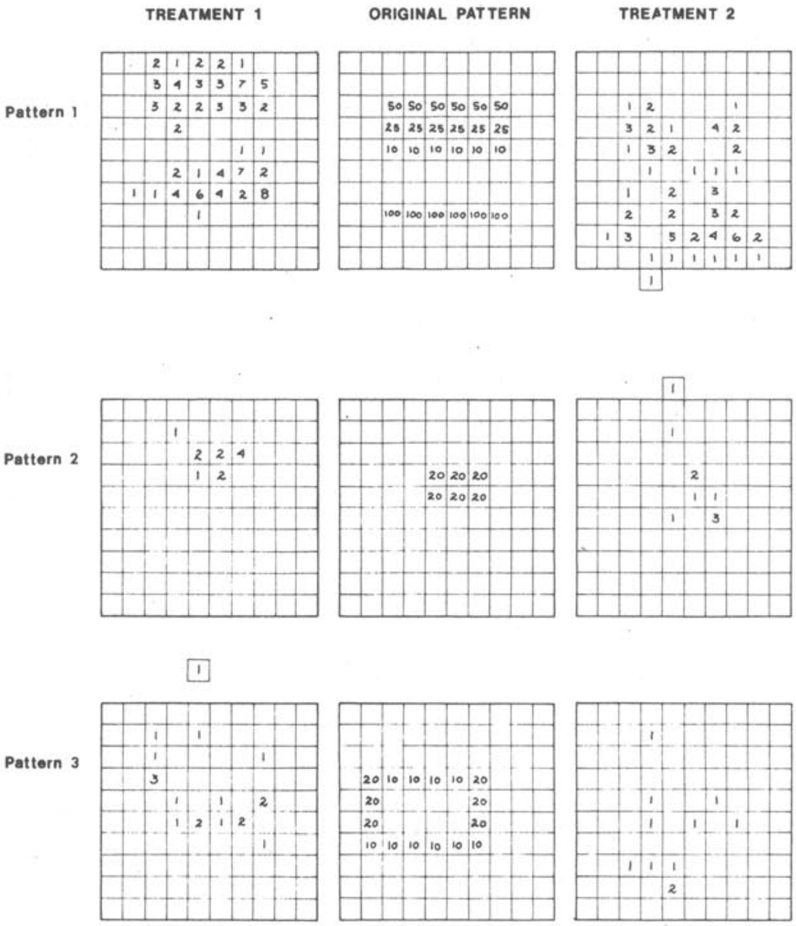


Figure 1.4. Number of <1>1/2 inch artifacts per grid square.

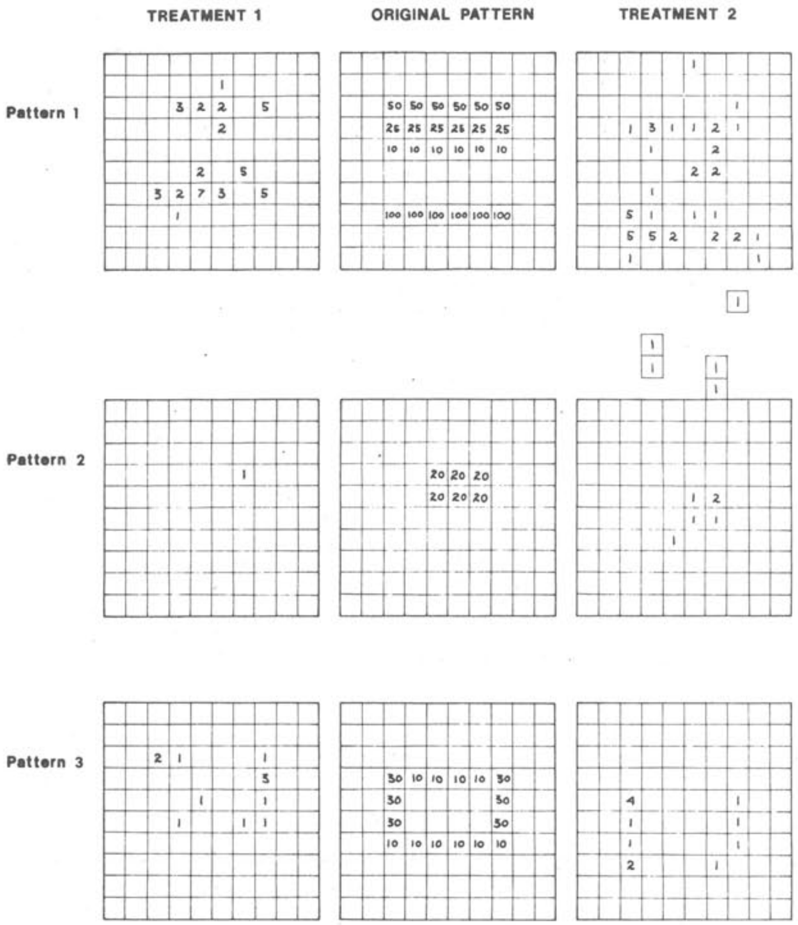


Figure 1.5. Number of <1/2 inch artifacts per grid square.

Third, long term effects of dispersion might be underestimated after only three equipment passes, but again, general trends can be suggested and expected magnitude of changes defined.

TILLAGE INDUCED CHANGES IN SURFACE ARTIFACT FREQUENCY

Archeologists have recognized that surface materials represent only a sample of the total plowzone population (e.g., Kirkby and Kirkby 1976; Ammerman and Feldman 1978; Trubowitz 1978), with certain artifact classes being over or under represented on the surface relative to actual frequencies in the plowzone population. A number of archeological observations have documented greater than average frequencies of larger objects in surface contexts (Stockton 1973; Baker and Schiffer 1975; Baker 1978; Gifford 1978; Hughes and Lampert 1979), which has been labeled the "size effect" (Baker and Schiffer 1975; Baker 1978). In the course of implement design studies, agricultural engineering research has also demonstrated the existence of this process (Winkelblech and Johnson 1964; Gill and Vanden Berg 1967; Kouwenhoven and Terpstra 1979; Gill, personal communication). The process apparently can be accounted for by equations of solid-solid blending in particulate media which have been developed by chemical engineers (Fischer 1960; Harwood 1977; Williams 1976). In a review of processes which contribute to sorting and segregation of particulate materials, Williams (1976:245) determined that four properties of polysized particulate assemblages caused segregation: (1) differences in particle size, (2) differences in particle densities, (3) differences in particle shape, and (4) differences in particle resilience.

In all three disciplines, then, the importance of size and other attributes of objects has been noted in determining the nature of material on the surface of a polysized medium. With this in mind, a number of working propositions were formulated to specify relationships between tillage processes and frequencies of surface artifacts. There are a number of ways of making such evaluations. One is to look at the absolute frequency of artifact classes before and after tillage treatments and compare percentage change between them. Another is to compare the relative proportion of each class within an assemblage before and after tillage treatments. Fairly consistent changes in the first comparison might still produce drastic differences in the second. This will be evaluated below.

Perhaps the best way to begin is to examine the frequency and proportion of large artifacts on plowzone surfaces. This can be done through testing the following propositions:

P_1 Compared to control assemblages, a higher percentage of large objects than small objects will be recovered following tillage.

P_2 Large artifacts will show an increase in relative proportion in tilled assemblages as compared to control assemblages.

These two related propositions represent a restatement of the "size effect", and, based on agricultural engineering studies, are expected to hold true in plowed fields. For example, one of the goals of cultivation is to bring fairly large rocks and soil clods to the surface to minimize erosion and at the same time to prepare a subsurface zone of fine particles to promote seedling growth (Gill and Vanden Berg 1967). Tillage equipment is designed with these goals in mind, which has the following implications for frequency of surface artifacts: given a population of artifacts in the plowzone, one would expect to recover on the average a higher percentage of large things in surface assemblages, compared to initial population. As a consequence, relative proportions of large things will increase, regardless of initial proportions.

Relative frequencies of different size classes might seem as if they are drawn from similar initial population sizes (see n values for treatments in Tables 1.1 and 1.2). For example, Treatment 1 has 25, 126 and 56 artifacts recovered for each size class, figures which are more or less on the same order of magnitude. However, 1" objects came from an initial population of 120 artifacts, while 1/4" artifacts came from an initial population of 1,510. This difference in recovery rates changes the relative proportions of each size class within Treatment 1 surface assemblages.

Propositions 1 and 2 can be evaluated by simple inspection of Tables 1.1 and 1.2. Proposition 1 is substantiated through inspection of "% OF CON" columns in Table 1.1. In all patterns for both Treatments 1 and 2, large artifacts are recovered at a higher rate than are 1/2" and 1/4" objects. There is a consistent monotonic decrease in percentage of original population recovered by decrease in object size. For example, Pattern 1, Treatment 1, shows recovery rates of 22.22%, 8.56%, and 3.87% of the control population for 1", 1/2", and 1/4" objects. Table 1.2 also illustrates a similar relationship between object size and recovery rate of original population, with data from Table 1.1 combined and summarized by size class and population.

Proposition 2 also is supported. Examination of the "% DIF % CON" columns in Table 1.1 reveals that the relative proportions of large artifacts within surface assemblages increase in post-tillage samples compared to control populations.

Propositions 1 and 2 are very general statements which account for size class frequencies in tilled surface assemblages. More specific propositions can be framed to examine the relationship between proportions of different size classes and duration of tillage:

P_3 An increase in the number of tillage operations will result in higher recovery rates of large objects.

P_4 An increase in the number of tillage operations will result in higher relative proportions of large artifacts to small artifacts.

Propositions 3 and 4 deal with duration of tillage and expected consequences on size class frequencies. Part of the rationale for formulating these hypotheses is derived from tillage studies which have demonstrated a direct relationship between number of equipment operations and degree of particle segregation by size (Winkelblech and Johnson 1964; Kouwenhoven and Terpstra 1979). Following approximately 10 to 15 operations, a threshold develops where continued tillage fails to cause further segregation. As noted in previous cautions about limitations of the experiment, three equipment passes (Treatment 2) may not be sufficient to detect development of frequency thresholds by size of object.

Inspection of Tables 1.1 and 1.2 does not support either proposition. The tables show fairly consistent decreases in the percentage of 1" objects by treatment compared to the control population under the columns "% OF CON" in Table 1.1 and "% OF CONTROL" in Table 1.2. One-half inch artifacts follow the same pattern, but 1/4" artifacts show an opposite trend. Thus, behavior of the data is in exactly the opposite direction than that predicted by the hypotheses. Similarly, relative proportions of large objects within patterns decrease rather than increase between treatments, as indicated by columns "% T_1", "% T_2", "% DIF T_1" and "% DIF T_1 CON". Large artifacts in both treatments do, however, retain higher recovery percentages and proportional values relative to small artifacts, indicating that they are overabundant relative to their position in the original population. This is expected if the "size effect" is operating.

Intuitively, it would seem that objects at opposite ends of the size continuum would behave differently, while those in the middle would exhibit some characteristics of both extremes. This relationship can be examined by inspection and by use of contingency table analysis. Inspection of Tables 1.1 and 1.2, as noted, suggests that 1" objects and 1/4" objects have different recovery trends. Behavior of 1/2" objects conforms more closely to that of 1" objects, with decreases in recovery percentage relative to initial population and decreases in relative proportion of surface assemblages accompanying increased duration of tillage. Relationships between size classes and treatment are evaluated by contingency table analysis, as presented in Tables 1.3 to 1.5. In general, proportions of 1" artifacts show little difference between treatments compared to 1/2" objects (Table 1.3), and more difference compared to 1/4" objects; this difference is not, however, statistically significant at the .05 level (Table 1.4). There are more significant differences between the two smaller size classes (Table 1.5), and even greater differences between the smallest size grade and the combined larger size classes (Table 1.6). Although the ϕ^2 values are not particularly large, which would indicate marked directional shifts in relative proportions between size classes, the consistent χ^2 values and two significant relationships above the .05 level (Tables 1.5 and 1.6) do seem to substantiate the notion of different recovery processes operating on 1/4" artifacts compared to larger objects.

What factors might account for this relationship? Disk plows invert a soil slice, moving the initial surface to the bottom of the disked furrow. Surface artifacts which are part of the soil fabric and which flow in the same fashion as soil particles move to the bottom of the plowzone after one equipment pass. Artifacts not flowing in the same fashion as soil particles are not incorporated to the same degree. Referring again to chemical engineering studies, small, flat artifacts flow better than larger, blockier artifacts, holding material constant. More small than large artifacts are incorporated in the first equipment pass, as the data clearly indicate. Further tillage incorporates more large artifacts while simultaneously bringing back to the surface small artifacts initially placed on the furrow bottom. Again, Tables 1.1 and 1.2 show this to hold for Treatment 2. Further trials are necessary to completely evaluate Propositions 3 and 4.

A final proposition based primarily on artifact size can be developed from expected incorporation characteristics of different sized objects. As noted, large objects are less likely to be incorporated into the plowzone soil matrix as readily as small objects and incorporation is more erratic and less predictable. Archeologists have noted fluctuations in distribution of large objects, mainly in the context of dispersion (e.g., Robertson 1976; Trubowitz 1978; Ball 1978; Jermann 1978). Ammerman and Feldman observe:

> What is less obvious is the implication that under varying surface conditions the chance of a given piece being recovered is *not* independent of its size. Larger pieces will have a *greater* chance of being found even when conditions are less than ideal (Ammerman and Feldman 1978).

Large objects appear to be subject to more movement partially because they are more frequently exposed on the surface and

Table 1.3. X^2 of >1 Inch vs. <1≥1/2 Inch Artifacts by Treatment.

	TREATMENT 1		TREATMENT 2		
SIZE	OBSERVED	EXPECTED	OBSERVED	EXPECTED	TOTALS
>1	25	23.2	15	16.8	40
<1≥1/2	126	127.8	94	92.2	220
TOTALS	151		109		260

X^2=0.38, df=1, p=>.50, $\varnothing^2$=0.001

Table 1.4. X^2 of >1 Inch vs. <1/2 Inch Artifacts by Treatment.

	TREATMENT 1		TREATMENT 2		
SIZE	OBSERVED	EXPECTED	OBSERVED	EXPECTED	TOTALS
>1	25	19.6	15	20.4	40
<1/2	56	61.4	69	63.6	125
TOTALS	81		84		165

X^2=3.80, df=1, p=>.05, $\varnothing^2$=0.023

Table 1.5. X^2 of <1≥1/2 Inch vs. <1/2 Inch Artifacts by Treatment.

	TREATMENT 1		TREATMENT 2		
SIZE	OBSERVED	EXPECTED	OBSERVED	EXPECTED	TOTALS
<1>1/2	126	116.1	94	103.9	220
<1/2	56	65.9	69	59.1	125
TOTALS	182		163		345

X^2=4.98, df=1, p=<.05. $\varnothing^2$=0.014

Table 1.6. X^2 of ≥1/2 Inch vs. <1/2 Inch Artifacts by Treatment.

SIZE	TREATMENT 1 OBSERVED	TREATMENT 1 EXPECTED	TREATMENT 2 OBSERVED	TREATMENT 2 EXPECTED	TOTALS
≥1/2	151	139.8	109	120.2	260
<1/2	56	67.2	69	57.8	125
TOTALS	207		178		385

$X^2=5.99$, $df=1$, $p=<.025$, $\phi^2=0.016$

Table 1.7. X^2 of Treatment vs. Size of Artifact by Large Population (Pattern 1).

SIZE	TREATMENT 1 OBSERVED	TREATMENT 1 EXPECTED	TREATMENT 2 OBSERVED	TREATMENT 2 EXPECTED	TOTALS
≥1/2	115	107.3	84	91.7	199
<1/2	43	50.7	51	43.3	94
TOTALS	158		135		293

$X^2=3.73$, $df=1$, $p=>.050$, $\phi^2=.013$

Table 1.8. X^2 of Treatment vs. Size of Artifact by Medium Population (Pattern 3).

SIZE	TREATMENT 1 OBSERVED	TREATMENT 1 EXPECTED	TREATMENT 2 OBSERVED	TREATMENT 2 EXPECTED	TOTALS
≥1/2	19	17.2	11	12.8	30
<1/2	12	13.8	12	10.2	24
TOTALS	31		23		54

$X^2=.97$, $df=1$, $p=>.25$, $\phi^2=.018$

less frequently incorporated into the soil. Consequently, one would expect somewhat more fluctuation between treatments to be reflected in larger size class recovery rates compared to smaller size classes. This can be stated:

P_5 Small artifacts will have more consistent recovery rates than large artifacts.

P_6 Small artifacts recovered will have more consistent relative proportions compared to proportion in control populations, than large artifacts.

Inspection of Tables 1.1 and 1.2 illustrates a complex series of relationships. One-quarter inch artifacts do show more consistent percent of original population between trials. Column "% DIF % T_1 % CON" in Table 1.2 compares changes in percentage of original population between Treatments 1 and 2 and shows a monotonic decrease in differences by size between treatments. Table 1.1 also shows less drastic changes for small objects in "% OF CON" columns between treatments.

When comparing relative proportions of each size class within sample assemblages, small objects show considerably more variation. This is indicated in Table 1.1 by columns "% DIF % CON" which compare relative proportions to original population. One-quarter inch objects are drastically underrepresented in Treatment 1 and less so in Treatment 2, while large artifacts are proportionally overrepresented in both. Table 1.2 reflects the same relationship in columns "% T_1", "% T_2"and "% T_1 - % T_2".

Based on these results, P_5 is supported and P_6 is not. Even though percentage of original population for small artifacts is fairly constant between treatments, fluctuations in relative proportions of small artifacts within treated assemblages are drastic. Why? It is safe to again invoke the previously discussed operating characteristics of disk plows and short duration of tillage. It is probable that continued tillage operations would result in approximate expectations of both P_5 and P_6. For example, values for Treatment 2 in both Tables 1.1 and 1.2 show that relative proportions of each size class more closely approximate original relative proportions. By looking at only one and three equipment passes, we see maximum fluctuations in the smallest size class, which distorts the relative proportion calculations.

Moving away from effects of artifact size, we now investigate the relationship between initial population and sample size after treatment, based on the laws of chance that larger populations will have less fluctuation in recovery rates than smaller populations. For example, given a population of objects (the control group) on the ground surface, which represents roughly a two-dimensional plane, tillage disperses the material into a three-dimensional block approximately 20 cm deep by 20 cm long by five cm wide (a rough estimate based on tillage studies, especially Sinekov 1979). Holding object size constant, it is probable that larger initial populations result in recovery of a larger sample. This can be phrased somewhat more precisely:

P_7 Holding artifact size constant, initial population size will condition post-tillage recovery rates.

P_8 Holding artifact size constant, initial population size will condition post-tillage proportions of artifact size classes.

In order to evaluate these propositions, values for each pattern, presented in Table 1.1, can be utilized. Pattern 1 represents a large population for each size class; Pattern 2, a small initial population; and Pattern 3, an intermediate population. Proposition 7 suggests that less variation exists in Pattern 1 percentage of original population values than that for Pattern 2. Examination of the column labeled "% DIF % CON", for each treatment, shows that larger populations do have less drastic differences than smaller populations, for both treatments. For example, 1" artifacts in Pattern 1, with an initial population of 90, have values of +8.75 % and +3.51 % for T_1 and T_2, respectively. One inch objects in Pattern 2, with an initial population of 30, have values of +16.67 % and +13.89 % for T_1 and T_2. The same fluctuations caused by initial population size appear in the "% OF CON" column, where Pattern 2 shows more variation (holding size constant). Thus Proposition 7 does account for pattern in recovery of artifacts on the plowzone surface. The same trend is apparent in Table 1.2, especially for cores and projectile points, which have extremely small initial populations. When Pattern 3 is also considered, trends in recovery rate more closely approximate those in the much larger Pattern 1 than Pattern 2, which has a population within 160 objects of Pattern 3. This suggests a population threshold between 120 and 220 objects effects recovery of the two smaller size classes. A similar threshold probably operates for recovery of large objects, but since the largest population of 1" objects in any pattern is only 90, the exact threshold is difficult to determine.

In summary it is suggested that some fluctuations in recovery rates of 1" objects do not result from size of object alone but are also likely due to initial sample size. Degree of influence of sample size cannot be ascertained with our results.

Proposition 8 is also supported. Relative proportions of artifacts recovered in each size class fluctuate somewhat more in Pattern 2 than in Pattern 1. Using columns "% T_1", "% T_2", "% DIF % CON" in Table 1.1, one can see the effects of small vs. large populations, again holding object size constant.

The complex nature of relationships between size of object and initial population size is further demonstrated in Table 1.2, where large populations (Pattern 1) are compared to small populations (Patterns 2 and 3), holding object size constant. If artifact size is ignored, there are no differences in recovery rates from large and small populations subjected to the two tillage treatments. This occurs because increases in recovery rates of large artifacts are offset by decreases in recovery rates of small artifacts. Implications of this result will be discussed below.

Contributions of population size and size of object are presented in Tables 1.7 through 1.9, using contingency table analysis. Judging by shifts in significance levels with changes in population, population size has an effect on recovery rates by size class. Examination of the phi-square values ($\emptyset^2$), which control for effects of sample size, shows that the basic relationship is not highly directional. Thus significance levels should be interpreted with some caution. The largest phi-square value occurs in Table 1.9, which has the smallest population size. Table 1.9 can be compared to Table 1.5 to observe the relationship between Pattern 2 and all patterns combined, for large and small artifacts. It is interesting to note that the smallest artifact population (Pattern 2) has a similar significance level and the same trend as the entire sample assemblage.

Having dealt with the relationships between recovery rates vs. object size and initial population size, we now examine the role of tillage duration on surface population. Differences between trials have already been examined; here we will evaluate effects of duration of tillage on recovery rates. Two propositions can be formulated:

P_9 Increasing duration of tillage will lessen differences in recovery rates between treatments.

P10 Increasing duration of tillage will lessen differences in relative proportions of size classes between treatment.

To outline the rationale for these two propositions, we must reiterate previous discussion of equilibrium states in plowzone particle structure and operating characteristics of tillage equipment. Returning again to the volumetric model of a plowzone, items placed on a surface are dispersed by tillage into a larger volume (surface + sub-surface area), but at differential rates by object size. One would therefore expect a drastic drop in frequency of surface material after initial tillage, but fewer differences among tillage surfaces as mixing of material throughout the plowzone brings objects to the surface at fairly standard rates. This would closely approximate equilibrium states previously discussed for agricultural engineering research.

Although only two trials were conducted, it is possible to determine whether trends suggested by P_9 and P_{10} develop. In order to test P_9, Table 1.1 Columns "% OF CON" for Treatment 1 and "% T_1" for Treatment 2 are used, and both agree with predictions of the propositions. Treatment 1 shows drastic reductions in frequency of artifacts, averaging less than 20% of the control population. A similar kind of comparison can be made between T_1 and T_2. As expected, Treatment 2 frequencies average over 70% of Treatment 1 frequencies, showing higher recovery rates between tillage treatments. A more compact summary of the trend is presented in Table 1.2 in "% OF CONTROL" in Treatment 1 and "% T_1" in Treatment 2.

Proposition 10 is less firmly supported and does not appear to account for patterns represented in Tables 1.1 and 1.2. Apparently, equilibria have not had time to develop in relative proportions of size classes. For example, relative proportions of Treatment 2 classes more closely approximate initial proportions than those of Treatment 1, as indicated in Table 1.1 columns "% DIF CON" and "% DIF T_1%". It appears that Treatment 2 represents the beginning of fairly stable recovery rates, and that further tillage would create relative proportions following more closely the predictions of P_{10}. The fact that relative proportions of size classes in Treatment 2 more closely approximate control group proportions is probably the most important observation made thus far. Although this relationship is probably a result of the short term duration of tillage, if it were to remain constant over many equipment passes, relative proportions of artifacts from plowzone surfaces could be used with considerable confidence, minimizing the "size effect" principle.

To briefly summarize analysis of tillage induced changes in surface artifact class frequencies, there are fairly consistent relationships between object size, initial population size, and duration of tillage. Higher percentages of large objects and objects from large populations are recovered on post-tillage surfaces as compared to control populations. Relative proportions of artifact classes are conditioned by artifact size, initial population size, and number of equipment passes. Small artifacts provide more constant recovery rates but fluctuate somewhat more in their relative proportions within tilled assemblages. Increasing the duration of tillage reduces differences in recovery rates between size classes and relative proportions of size classes more closely approximate control group proportions.

This leads to another important question: what frequencies of each size grade will be recovered if long term tillage is carried out?

Based on the observed pattern, assuming all hypotheses operate on plowzone material, and employing the same populations as those in the experiment, Fig. 1.6 presents projected recovery rates of three size classes by percentage of control population and relative proportions in surface assemblages for 21 equipment passes. With increased diskings, it is proposed that the "size effect" segregation process would begin to operate, resulting in greater discrepancies between recovery rates of size classes. This alters relative proportions of each size class in surface assemblages. Since small flakes appear to more closely conform to movement characteristics of soil particles, it seems likely that they would provide a stable measure by which to estimate percentage of control assemblage recovered. If they do, then relative proportions of small objects can be used to transform frequencies of size classes in surface collected artifacts to approximate proportions in the original population. Thus, it should be possible to "calibrate" tillage effects on surface assemblages by using small artifacts. This, of course, assumes fairly straight-forward linear relationships between object size, tillage processes, and recovery rates of surface objects. Agricultural and chemical engineering research suggests this should be the case, but more work must be carried out on archeological materials to establish precise relationships among these variables.

TILLAGE INDUCED LATERAL DISPLACEMENT

The previous section emphasized changes in class frequencies of surface assemblages. These also relate to lateral displacement of objects, for some size classes appear to be subject to greater amounts of lateral displacement than others. In this discussion we will make comparisons which sum displacement across size classes in order to examine general trends in pattern dispersion. Other propositions assess the role of object size and initial population size on pattern alteration. As a consequence, some preliminary guidelines can be suggested for minimizing tillage effects for pattern analysis of plowzone surface artifacts.

Archeologists have long been concerned with lateral displacement of surface materials by cultivation (Binford *et al*. 1970; Redman and Watson 1970; Roper 1976; Talmage and Chesler 1977; Trubowitz 1978) primarily in terms of the relationship between surface and subsurface artifact assemblages. That is, does pattern in surface materials provide useful information to determine where to excavate? Lateral displacement

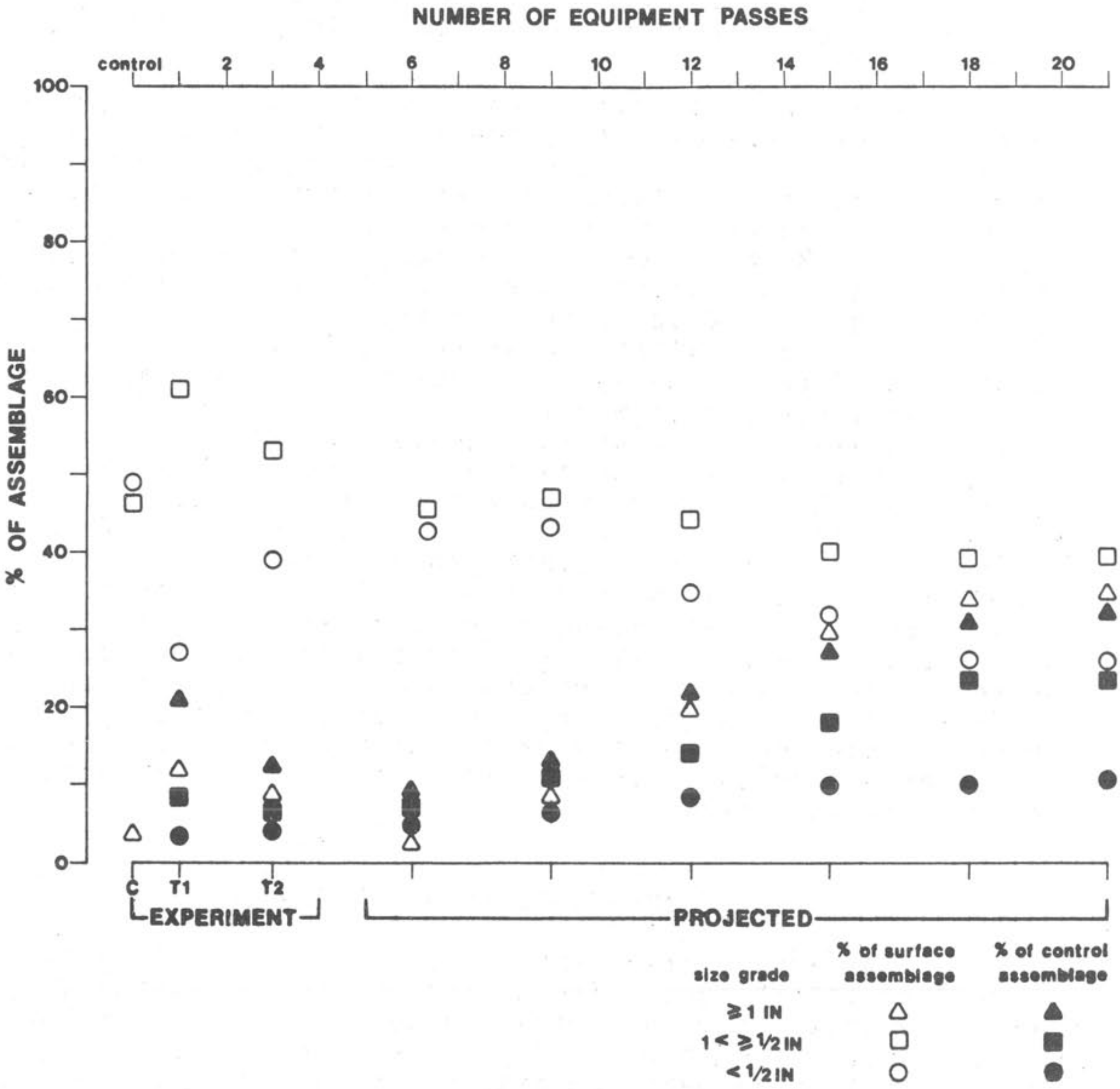


Figure 1.6. Relationship between recovery of surface artifacts by size and number of equipment passes.

actually consists of two kinds of movement: (1) longitudinal movement or displacement in the direction of tillage equipment movement and (2) transverse movement, or displacement away and perpendicular to the working surface of the implement (Nartov 1979). Depending on design parameters, various kinds of implements produce different amounts of longitudinal and transverse displacement. For example, moldboard plows produce higher transverse movement than do disk plows. Because most force is exerted in the direction of equipment movement, longitudinal dispersion of objects will generally be greater on the average than transverse displacement for all implement types.

In order to assess pattern size, maximum vertical and horizontal distances were measured for each pattern by number of squares between pattern extremes. Tillage induced changes in the vertical dimension are equated with longitudinal displacement; horizontal changes are equated with transverse displacement. For the purposes of hypothesis testing, each is treated independently, although horizontal movement is conditioned to some degree by vertical movement. These relationships are lessened by measuring by blocks rather than by exact provenience of objects.

We begin examination of pattern dispersion by stating a very general proposition about expected direction and magnitude of changes:

P_{11} Longitudinal displacement of artifacts will be greater than transverse displacement.

This proposition is suggested by archeological observations (e.g., Robertson, in Talmage and Chesler 1977) and by design parameters of tillage implements. Both Table 1.1 and Table 1.10 demonstrate much greater change in vertical dimensions of patterns as compared to horizontal dimensions. Disregarding effects of artifact size and initial population size, the higher average longitudinal displacement can be statistically tested, as presented in Table 1.11. Here, vertical and horizontal displacement are compared by treatment. Appropriate statistics are those which compare average values between independent samples. Since not all assumptions are necessarily met for any single statistical test, we have applied three related techniques in order to test the following null hypothesis: there is no statistical difference between vertical and horizontal movement of objects within the same treatment. The same trend is apparent throughout all tests: there is significant statistical difference between vertical and horizontal movement beyond the .025 level.

Since longitudinal movement appears to be greater, duration of tillage might be an important contributing factor. Effects of long term plowing have been a major concern of archeologists, again in the context of surface to subsurface assemblage con-

Table 1.9. X^{2*} of Treatment vs. Size of Artifact by Small Population (Pattern 2).

	TREATMENT 1		TREATMENT 2		
SIZE	OBSERVED	EXPECTED	OBSERVED	EXPECTED	TOTALS
>1/2	17	12.7	14	18.3	31
$\bar{<}$1/2	1	5.3	12	7.7	13
TOTALS	18		26		44

X^{2*}=6.58, df=1, p=<.025, ϕ^2=.150
* Calculated with Yates' Corection for Continuity.

Table 1.10. Average Change in Maximum Pattern Dimensions.*

	VERTICAL DIMENSIONS			HORIZONTAL DIMENSIONS		
CLASS	N	$\overline{X}$	σ	N	$\overline{X}$	σ
>1	4	3.75	2.50	4	0.25	0.96
<1$\bar{>}$1/2	6	3.83	2.48	6	0.67	0.82
$\bar{<}$1/2	6	1.83	4.07	6	-0.17	0.98
LARGE POPULATION	8	5.13	4.02	8	1.13	0.64
SMALL POPULATION	8	2.79	2.29	8	-0.07	0.73
TREATMENT 1	11	2.00	1.90	11	0.27	0.95
TREATMENT 2	11	5.27	3.38	11	0.45	0.93

* Data from Table 1.1.

TEST		TREATMENT 1			TREATMENT 2			TREATMENTS 1 AND 2		
		VERTICAL DISPLACEMENT	VS	HORIZONTAL DISPLACEMENT	VERTICAL DISPLACEMENT	VS	HORIZONTAL DISPLACEMENT	VERTICAL DISPLACEMENT	VS	HORIZONTAL DISPLACEMENT
TWO SAMPLE T-TEST	N=	11		11	11		11	22		22
	$\bar{X}$=	2.00		0.273	5.273		0.455	3.636		0.364
	σ=	1.90		0.905	3.38		0.934	3.16		0.902
	DF=		14			11			24	
	P=		.0164			.0000			.0000	
POOLED T-TEST	DF=		20			20			42	
	P=		.0130			.0000			.0000	
MANN-WHITNEY TWO SAMPLE TEST	MD=	2.00		0.00	4.00		2.00	3.00		0.00
	W=		162.0			177.0			663.5	
	P=		.0215			.0010			.0001	

Table 1.11. Comparison of Vertical and Horizontal Displacement of Maximum Pattern Dimensions.

gruity. Using pattern of equipment movement as a guide, one might expect somewhat gradual increases in longitudinal movement of artifactual material through time. For example, Fig. 1.7 shows one of the most common plowing patterns recommended by the International Harvester Company (Stone and Gulvin 1967:Fig. 9.17). Maximum efficiency in equipment use means few sharp turns, and roughly equal numbers of equipment passes in each direction. This minimizes possible cumulative directionality in longitudinal movement. For example, in Treatment 2, material which was moved south in the first disking was pushed in the opposite direction by the next equipment pass. The third disking, again southward, moved the material again in that direction. Redman and Watson (1970) liken this movement to random or Brownian Motion. However, there is somewhat more directionality built into the equation than they consider since longitudinal displacement outdistances horizontal movement over time, reducing the amount of randomness in object movement. Nevertheless, overall magnitude of lateral displacement is less than commonly assumed by archeologists (Roper 1976; Robertson, in Talmage and Chesler 1977; Trubowitz 1978).

We can frame archeologists' interest in long-term tillage effects in the following propositions:

P_{12} Amount of longitudinal movement will increase with duration of tillage.

P_{13} Amount of transverse movement will increase with duration of tillage.

In order to assess these propositions, both treatments are compared in Table 1.12. Statistics in Table 1.12 test the null hypothesis that there are no significant differences in average amount of dispersion between treatments. As in Table 1.11, there is a consistent trend among tests which demonstrates that the null hypothesis must be rejected for vertical (longitudinal) displacement, but may be retained when considering horizontal displacement. Thus, there appears to be a significant relationship between amount of longitudinal displacement and length of tillage. There does not appear to be a significant change in transverse displacement, at least after three equipment passes. Both treatments can also be compared to original pattern to determine if tillage induced pattern changes are statistically significant.

Table 1.13 uses the Wilcoxon-Signed Ranks Test between dependent variables to assess the amount of difference in displacement caused by disking. Both treatments show significant differences in vertical displacement when compared to control pattern but no significant differences in horizontal displacement (although Treatment 2 had too few cases to use the test for horizontal displacement).

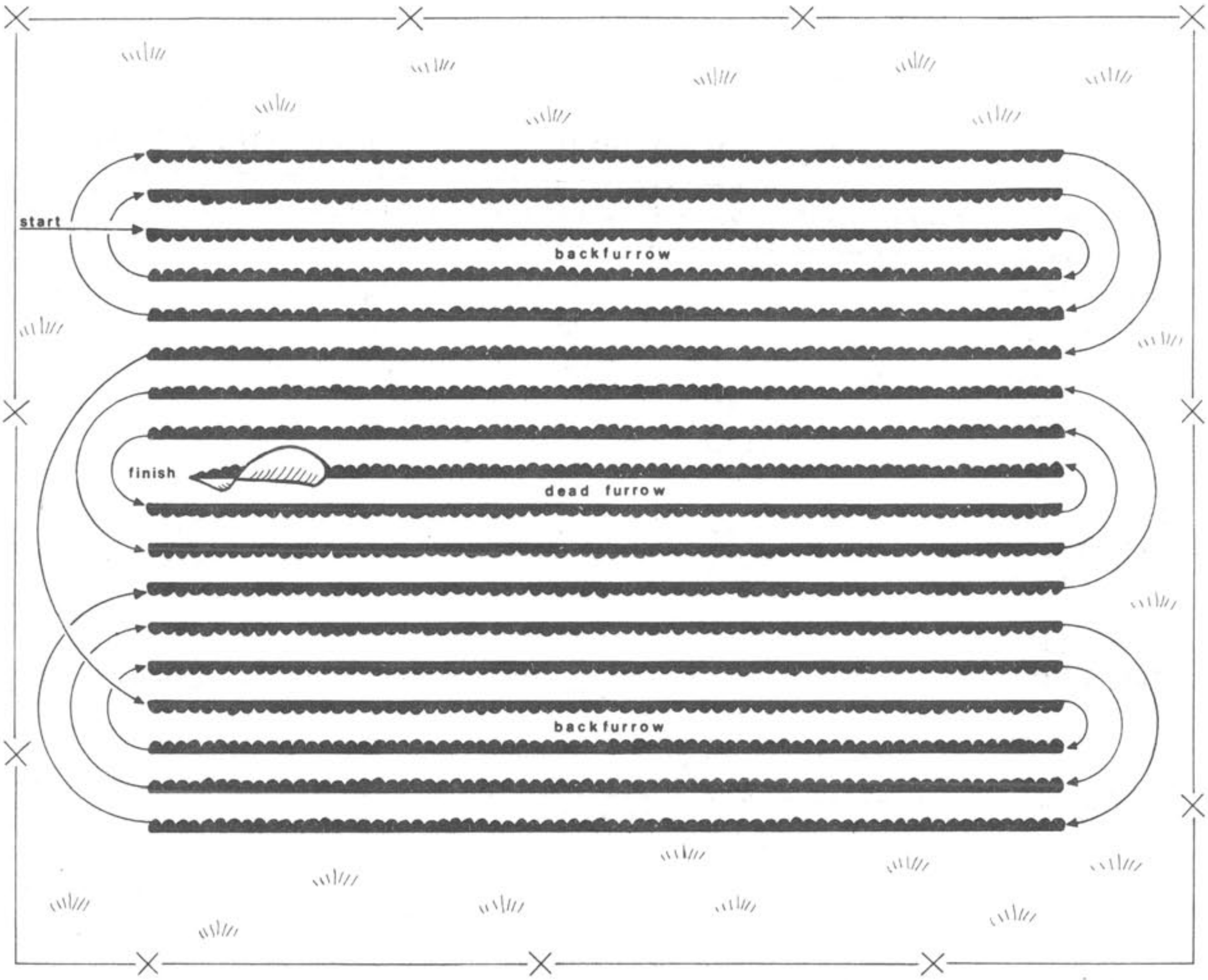


Figure 1.7. Typical plowing pattern recommended by the International Harvester Company.

Table 1.12. Comparison of Treatments by Vertical and Horizontal Displacement.

	VERTICAL DISPLACEMENT			HORIZONTAL DISPLACEMENT		
TEST	TREATMENT 1	VS	TREATMENT 2	TREATMENT 1	VS	TREATMENT 2
TWO SAMPLE						
T-TEST N=	11		11	11		11
$\bar{X}$=	2.000		5.273	0.273		0.455
σ=	1.90		3.38	0.905		0.934
DF=		15				
P=		.0134				
POOLED						
T-TEST DF=		20			20	
P=		.0110			.6478	
MANN-WHITNEY						
TWO SAMPLE						
TEST MD=	2.00		4.00	NO DIFFERENCE		
W=		92.0				
P=		.0256				

Table 1.13. Wilcoxon-Signed Ranks Test of Control Versus Tillage Pattern Dimensions.

CONTROL - TREATMENT 1		CONTROL - TREATMENT 2	
VERTICAL DISPLACEMENT	HORIZONTAL DISPLACEMENT	VERTICAL DISPLACEMENT	HORIZONTAL DISPLACEMENT
N = 10	N = 6	N = 10	N = 5***
T = 2.5	T = 0.6	T = 0	T =
p = <.02* <.01**	p = >.05*	p = <.01* <.005**	p =

* p for Two-Tailed Test

** p for One-Tailed Test

*** Test cannot be applied to N<6.

A cautionary note about generalizing from these results is mentioned here. Measurements represent maximum dispersion away from initial pattern boundaries. Many of the measurements use individual outliers, i.e., extremes of pattern dispersion, rather than average number of artifacts forming a coherent boundary. It is likely that outliers would not be taken into account during analysis of archeological surface collections; emphasis would instead be placed on coherent boundaries defined by fairly high artifact densities. Inspection of Figs. 1.2 through 1.5 indicates that most of the longitudinal displacement can be accounted for by outliers. Removal of these reduces longitudinal displacement by over 50%. In addition, both vertical and horizontal displacement measurements represent maximum N-S, E-W movement of pattern, so average dispersion in any one direction is one-half the total values shown in the tables. If both limitations are taken into account when gauging pattern dispersion, average horizontal movement in any one direction is less than 40 cm, and average vertical displacement is under three meters. Figures 1.2 through 1.5 also demonstrate that patterns, though offset relative to original pattern location, retain a high degree of spatial coherence. This aspect will be discussed in more detail later.

Having established that longitudinal displacement is a significant factor in pattern dispersion, we now examine some of the variables which might account for this process: object size and initial population size. Based on prior discussions of object size, we can generate two related propositions:

P_{14} Larger objects will have higher average displacement values.

P_{15} Smaller objects will have lower average displacement values.

Background data which aided in development of propositions 5 and 6 are also relevant here. In addition to Trubowitz's (1978) observations that larger objects tend to move farther than smaller objects, Talmage and Chesler (1977:24-25) summarize Robertson's assessment of tillage induced dispersion which notes long distance movement of bricks placed within a prehistoric lithic scatter even though the boundaries of the scatter remained intact. Robertson is quoted as stating:

> Although the sample size is small, the results are characterized by confusion and disparity in how individual pieces will be disturbed by the plow... results from the first set of collections [prehistoric lithic scatter] where plowing had relatively little effect on the spatial distribution of remains contradicts experimental results [movement of bricks] (Talmage and Chesler 1977:24-25).

In spite of long term plowing, the lithic scatter retained a fairly coherent pattern, yet short term plowing drastically moved bricks throughout the field. Difference in size and shape of objects seems to be one of the most likely factors contributing to this discrepancy.

Preliminary assessment of trends in movement by object size (Tables 1.1 and 1.10), supports Propositions 14 and 15. Results presented in Table 1.10 demonstrate that large objects have higher average vertical displacement values than small objects, although small objects do have a larger standard deviation. Small objects also have lower average horizontal displacement values, but these differences are not statistically significant. Significance of trends in descriptive statistics are tested in Table 1.14, which compares vertical and horizontal displacement by object size and treatment. There are no statistically significant differences in average movement of large vs. small objects within each tillage treatment or by combined treatments. Thus, within a tillage treatment, objects of different sizes do not differ significantly in relative amounts of lateral displacement. Propositions 14 and 15 account for the trends in Tables 1.1, 1.10, and 1.14, but these trends are not statistically significant within the context of the experiment. The changes appear to be cumulative in nature. Table 1.15 changes the comparison between objects to evaluate differences in movement by treatment, holding object size constant. Thus, Table 1.15 tests the following proposition:

> P_{16} Large artifacts will have greater average displacement than small artifacts with increases in length of tillage.

This would be expected given the fact that: (1) large objects are found on the ground surface in greater relative proportions than are small objects and (2) would therefore be subject to greater displacement. Examination of Table 1.15 shows that the proposition appears to account for differences in vertical displacement of larger objects between T_1 and T_2. Small artifacts do not show significant differences in vertical displacement between treatments. Amount of horizontal displacement does not appear to vary significantly between treatments for either the large or small size class.

Having established the role of object size on dispersion, the next problem is to examine the role of initial population size. Small populations result in greater fluctuation in recovery rates; consequently, one might expect these populations to produce somewhat lower displacement values, since fewer objects are exposed on the surface. The logic which states that large objects are subject to greater displacement operates here as well, for larger populations will have more surface objects subjected to tillage induced displacement. Stated more precisely:

TEST		VERTICAL DISPLACEMENT						HORIZONTAL DISPLACEMENT					
		TREATMENT 1		TREATMENT 2		COMBINED		TREATMENT 1		TREATMENT 2		COMBINED	
		≥1/2	<1/2	≥1/2	<1/2	≥1/2	<1/2	≥1/2	<1/2	≥1/2	<1/2	>1/2	<1/2
TWO SAMPLE T-TEST	N=	5	3	5	3	10	6	5	3	5	3	10	3
	$\bar{X}$=	2.4	2.00	5.20	3.67	3.80	2.83	0.60	-0.67	0.40	0.33	0.50	-0.17
	σ=	1.67	1.73	2.17	5.51	2.34	3.76	0.55	1.15	1.14	0.58	0.85	0.98
	DF=	4		2		7		2		5		9	
	P=	.7648		.6899		.5888		.2165		.9171		.2009	
POOLED T-TEST	DF=	6		6		14		6		6		14	
	P =	.7573		.5850		.5336		.0740		.9295		.1733	
MANN-WHITNEY TWO SAMPLE	MD=	2.0	1.0	4.0	1.0	3.5	1.0	1.0	0.0	0.00	0.00	0.5	0.0
	W=	24.0		25.0		96		28.0		25.		96.0	
	P=	.7656		.5510		.2548		.1360		1.000		.2548	

Table 1.14. Comparison of Vertical and Horizontal Displacement by Object Size.

Table 1.15. Comparison of Vertical and Horizontal Displacement of Treatments by Object Size.

		VERTICAL DISPLACEMENT				HORIZONTAL DISPLACEMENT			
		≥1/2		<1/2		≥1/2		<1/2	
TEST		T 1 VS	T 2	T 1 VS	T 2	T 1 VS	T 2	T 1 VS	T 2
TWO SAMPLE									
T-TEST	N=	5	5	3	3	5	5	3	3
	$\overline{X}$=	2.40	5.20	2.0	3.67	0.60	0.40	-0.67	0.33
	O=	1.67	2.17	1.73	5.51	0.55	1.14	1.14	0.58
	DF=	7		2		5		2	
	P=	.0561		.6667		.7381		.3118	
POOLED									
T-TEST	DF=	8		4		8		4	
	P=	.0516		.6433		.7328		.2508	
MANN-WHITNEY									
TWO SAMPLE									
	MD=	2.0	4.0	1.0	1.0	1.0	0.0	0.0	0.0
	W=	18.5		11		29.5		8.0	
	P=	.0758		1.000		.7540		.3827	

P_{17} Larger populations will have higher average lateral displacement than smaller populations.

General trends in Tables 1.1 and 1.10 confirm expectations of the proposition, which suggest higher average vertical and horizontal displacement values for a large population compared to a small population. Large vs. small values in Table 1.10 are based on comparison of Pattern 1 with Pattern 2, summing displacement values for both tillage treatments.

To summarize short term tillage displacement of artifacts, significant differences in pattern size are found when comparing vertical dimensions between control pattern and tilled pattern. Vertical changes in pattern size are caused by longitudinal displacement, or dispersion in the direction of equipment movement. Increases in the number of tillage operations produce significant differences in the amount of longitudinal displacement between tillage treatments. There is no significant difference in horizontal dispersion between treatment and control patterns or within tillage treatments. Large artifacts show more longitudinal displacement between tillage treatments than do small artifacts, with amount of movement approaching a fairly high level of significance. Transverse movement is approximately equal for all size classes. Large initial populations also appear to have some effect on amount of displacement by increasing the likelihood that artifacts appear on the surface and are subject to greater movement.

EVALUATION OF RESULTS FOR INTERPRETATION OF SURFACE PATTERN

Assessment of population changes and lateral displacement has provided some general trends which appear to account for patterns of surface materials in plowzone contexts. These observations can now be applied to experimental results in order to best replicate control patterns. Two approaches will be taken, one using total number of artifacts for pattern definition, the other examining pattern replication using size classes of objects.

When comparing total number of artifacts in tillage treatments, effects of object size or initial population size tend to offset each other, allowing use of total number of artifacts for pattern replication. Using total number of artifacts recovered, then, what analysis techniques can be applied to replicate control patterns? At least two are immediately apparent: (1) changes in scale of analysis and (2) transformation of grid frequencies using various algorithms.

Changing scale of analysis is not an analytical technique *per se*, but it has the same effect of many transformation algorithms in that it minimizes effects of lateral displacement. Based on measurements of pattern dispersion, most changes in pattern boundary are less than two meters. Changing the scale of analysis from one meter squares to a grid of 2 x 2 m squares encompasses most movement of objects, and results in a close correspondence between control and treated patterns. This approach is demonstrated in Fig. 1.8, which graphically displays total frequencies per square by density shading scaled to total number of artifacts in Pattern 1. As can be seen in Fig. 1.8, there is a definite compromise in combining squares: while effects of lateral displacement are minimized, considerable detail is lost in the process, and replication of control pattern is not measurably enhanced, especially for Treatment 2. The same technique was applied to Patterns 2 and 3, with somewhat similar results (not presented here). Complexity of internal structure within a pattern seems to be the most important factor affecting utility of changes in scale. Pattern 2 is a homogeneous, compact pattern, and change in scale of analysis provides a good match with control pattern. Pattern 3, like Pattern 1, is fairly complex in terms of density shifts and internal structure of pattern and as was the case for Pattern 1, changes in scale of analysis of treated Pattern 3 plots did not represent an improvement for pattern replication.

A major problem in changing scale of analysis is that the technique treats both longitudinal and transverse displacement as equivalent, which our experimental results have demonstrated to be an incorrect assumption. Consequently, scaling overcompensates for horizontal displacement, with a concomitant loss in structural detail and ability to replicate control pattern. If such an approach is to be applied, it should probably be restricted to fairly homogeneous structural units such as Pattern 2.

Another approach to pattern replication employs a series of algorithms to transform and combine grid counts in order to minimize tillage induced changes. Several smoothing or grid count averaging formulas were applied with little success in approximating control patterns. Two techniques which do appear to be useful include a grouping formula that compares values in adjacent squares and a correction factor based on percent of control population recovered.

Both techniques were applied to Pattern 1, Treatment 2, which is the most complex pattern to analyze in the experiment and the most difficult to replicate. Using percentage of original population recovered in Treatment 2, a correction factor was estimated for different size classes. Counts of each size class in Figs. 1.3 through 1.5 were multiplied by the following factors: (1) 1" = 5; (2) 1/2" = 8; and (3) 1/4" = 10. Totals for all three size classes were then combined to form a new, corrected total number of artifacts plot. While this procedure attempted to control for differential

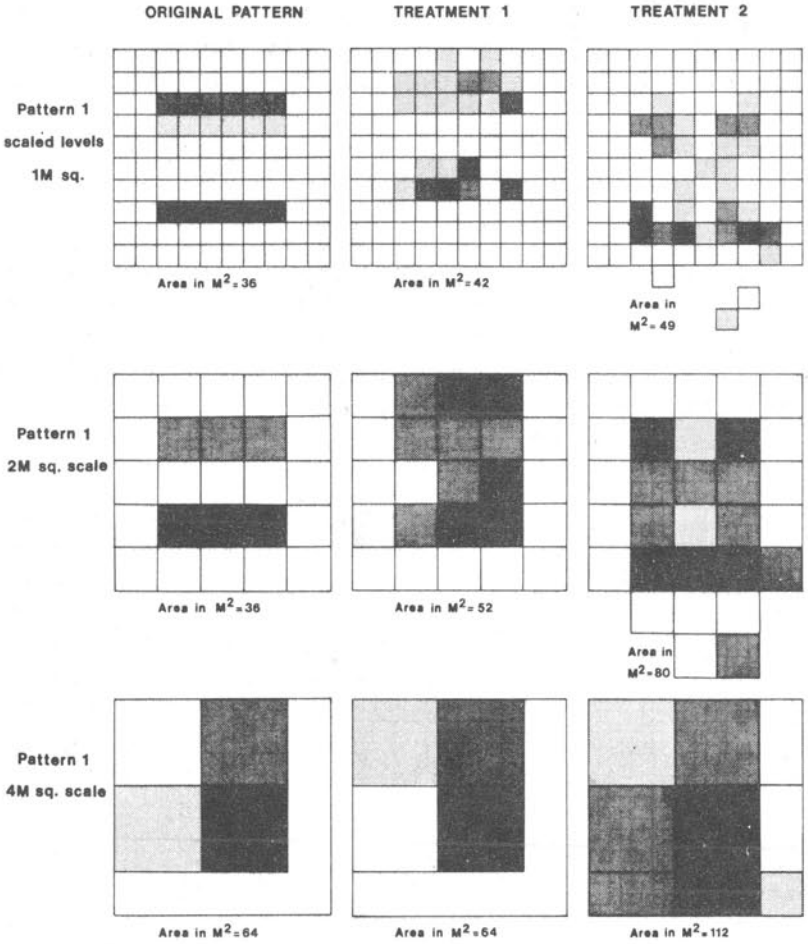
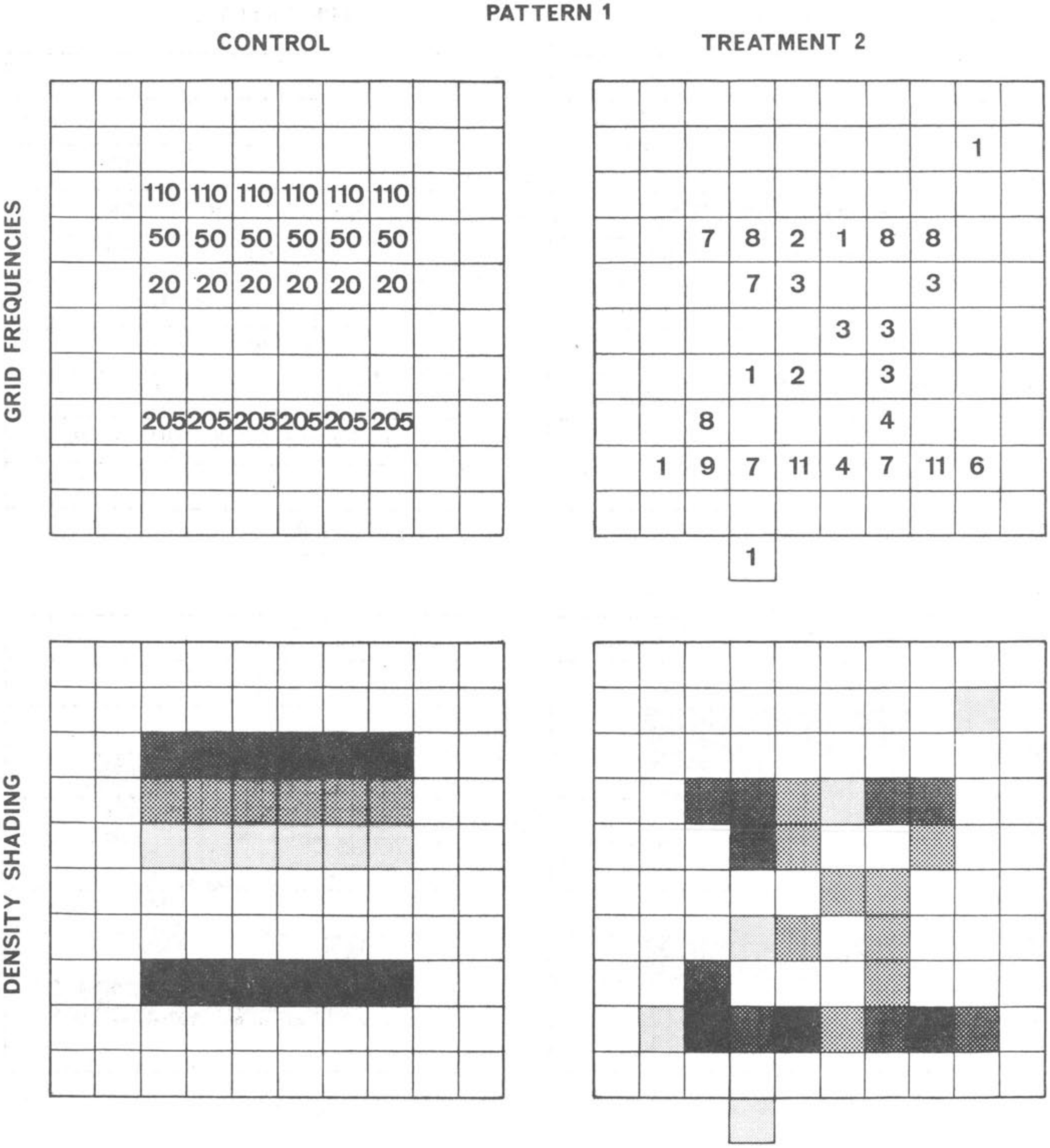


Figure 1.8. Density of total number of artifacts in Pattern 1 by 1 m, 2 m, and 4 m grid squares.

recovery by object size, it did not correct for longitudinal displacement. This displacement was minimized by using a grouping algorithm based on inspection of Figs. 1.2 through 1.5 and Tables 1.1 and 1.10. Moving from top to bottom in a column, artifact frequencies in vertically adjacent grid pairs were compared. If class frequencies in one square were less than or equal to 50% of the frequencies of an adjacent square, artifact counts were moved from the lower to higher density square. This procedure is analogous to gravity models used elsewhere in the social sciences which weight sphere of influence in proportion to size of largest local node. Rationale for the procedures is derived from the fact that tillage is a smoothing process which averages differences between low and high density values by moving artifacts from higher density squares at greater rates than from low density values. The rather unsophisticated grouping algorithm employed here attempts to "unsmooth" tillage values by roughly estimating how much material is removed from higher density squares. Even if such techniques do work in this case it should be reiterated that control patterns are fairly simple, tillage is of short duration, and we have prior knowledge about how materials move.

Results of correction for size and grouping by proportional weighting are presented in Fig. 1.9, which compares Pattern 1, Control and Treatment 2, by grid frequency and density shading of frequency data. The replicated pattern, corrected Treatment 2, has approximately correct distribution of density values at vertical extremes, shows a potential density gradient in the upper portion, and also indicates an area in the center of the pattern without material. Grid counts do not duplicate those of the control pattern, grossly underestimating counts in high density areas in spite of the application of a recovery rate correction algorithm.

Figure 1.10 compares Pattern 1, Treatment 2 grid counts with the control pattern, without correcting for differences in recovery by size. In this case, total number of artifacts is transformed by the same grouping algorithm, but not corrected by object size. This procedure produces somewhat better pattern replication, with approximate relative density relationships, approximate size of pattern, and better definition of internal structure of the pattern. Comparing Fig. 1.9 with Fig. 1.10, correction for differential recovery by object size does not produce an increase in precision of pattern replication. Although both results are useful, a more sophisticated grouping algorithm would provide improved congruence of tillage and control patterns by increasing the sphere of influence of high density grid squares and differentially weighting vertical displacement by object size. Given the small sample size and limitations of the experiment, this was not attempted.



		110	110	110	110	110	110		
		50	50	50	50	50	50		
		20	20	20	20	20	20		
		205	205	205	205	205	205		

								1	
		7	8	2	1	8	8		
			7	3			3		
					3	3			
			1	2		3			
		8				4			
	1	9	7	11	4	7	11	6	
			1						

Figure 1.9. Comparison of Pattern 1 by Control and Treatment 2, correcting for recovery by size class and grouping by proportional weighting.

PATTERN 1

CONTROL **TREATMENT 2**

GRID FREQUENCIES

CONTROL

		110	110	110	110	110	110		
		50	50	50	50	50	50		
		20	20	20	20	20	20		
		205	205	205	205	205	205		

TREATMENT 2

							18		
		55	67	23	10	72	26		
			52	21			24		
					28	28			
			10	16		24			
		74				34			
	8	82	68	89	34	60	76	26	
								18	
			8						

DENSITY SHADING

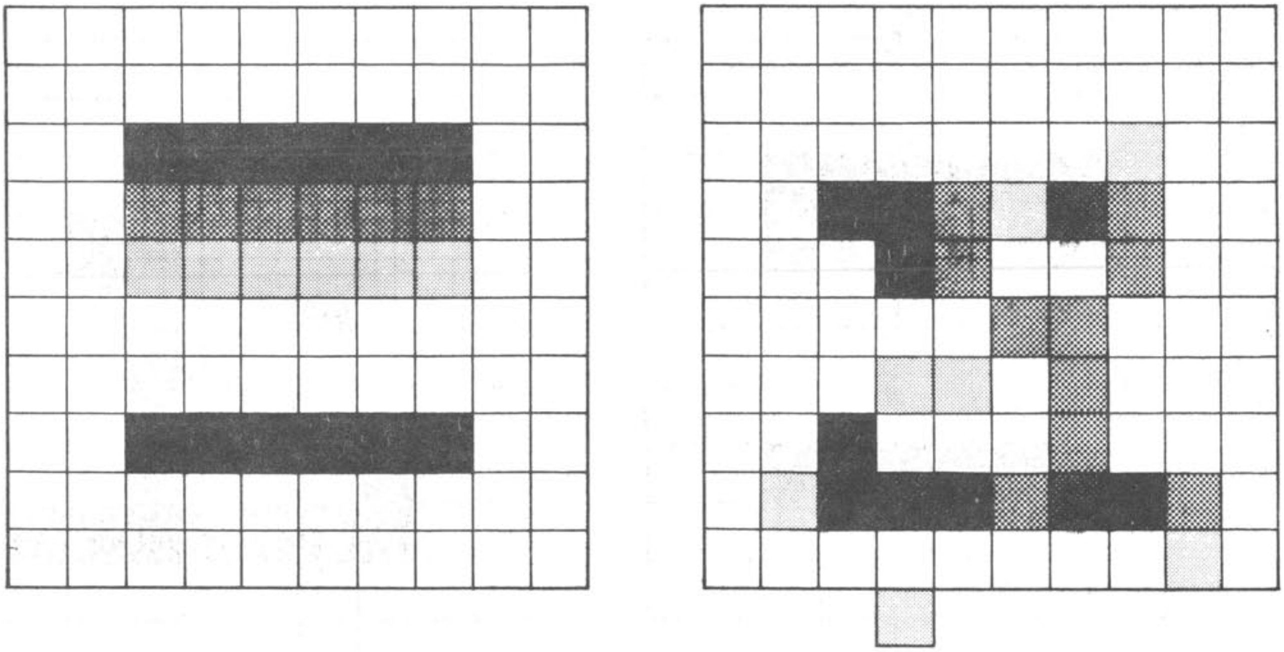


Figure 1.10. Comparison of Pattern 1 by Control and Treatment 2, grouping by proportional weighting.

What are the implications of this discussion for interpretation of surface pattern in plowzone archeological materials? First, limitations in the nature of the material must be realized. Surface assemblages likely represent less than 10% of the total plowzone population, with large objects proportionally overrepresented relative to small objects. Large artifacts are subject to greater average lateral displacement, especially in the direction of equipment movement. Nevertheless, patterns of plowzone materials are not as seriously disrupted as is often assumed. Only continued research can more precisely identify factors which must be taken into account when dealing with plowzone surface artifacts. In order to maximize the utility of interpretations based on surface material and minimize tillage effects, the following guidelines are offered:

1. obtain all possible information about tillage history of the field, including direction, equipment type, length of time under tillage, etc.;
2. collect in the smallest practical provenience unit;
3. plot total frequencies by provenience unit to "preview" pattern complexity;
4. using information from step 3, experiment with grouping algorithms to minimize "noise" introduced by tillage. Because small artifacts appear subject to less displacement, these should prove more useful for initial pattern definition; and
5. transformation algorithms should emphasize object size, longitudinal displacement, and proportional density grouping. Given the present limited state of knowledge, these will have to be tailored to fit requirements of each study.

CONCLUSIONS

Despite design limitations, the tillage experiment reported here represents preliminary research which identifies variables contributing to frequency and pattern of plowzone surface artifacts and suggests possible ways to lessen tillage induced bias in their analysis. Important factors affecting surface assemblages include: direction and number of equipment passes; size, shape, artifact density, and structural complexity of pattern; and frequencies and relative proportions of different sized artifacts. Other variables to consider in field situations are soil type, soil moisture, equipment type, post-tillage rainfall, and field techniques used for surface collection. Surface assemblages likely represent less than 10% of the total plowzone population, with large artifacts being recovered in greater proportions than smaller artifacts. Small artifacts have more constant recovery rates relative to original populations, and are not as subject to lateral displacement as are large artifacts. Initial population size also effects recovery of surface materials. Recovery rates are important determinants of lateral displacement of artifact pattern, with all artifacts subject to shifts in the direction of equipment movement, or longitudinal displacement. Large objects and large initial populations have greatest longitudinal displacement values. It is possible to approximate untilled control patterns using a transformation algorithm based on proportional weighting of grid counts in the direction of equipment movement. Although these density patterns have roughly the same shape and structure as control patterns, grid frequency estimates by size of artifact are markedly lower than in control assemblages.

It should be emphasized that these generalizations are a first attempt toward more precise quantification of tillage effects on archeological material. Further work using more equipment passes, larger assemblages, and different provenience recording techniques should allow formulation of fairly accurate equations describing relationships between tillage processes and subsequent pattern in archeological surface assemblages. Consequently, future research should allow more efficient use of that portion of the archeological record subject to cultivation.

ACKNOWLEDGMENTS

A special note of thanks goes to John E. Griffin who not only allowed the experiment to be carried out on his land but also provided and operated the farm machinery. Tom Miskell supervised field operations, including both establishing pre-tillage patterns and conducting post-tillage surface collection. The capable Cannon Reservoir Human Ecology Project Laboratory crew under the supervision of Nellie Swift and Tom Miskell sorted and counted the artifactual materials.

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THE INFLUENCE OF SAMPLING UNIT SIZE ON STATISTICAL ESTIMATES IN ARCHEOLOGICAL SITE SAMPLING

by
Jack D. Nance and Bruce F. Ball

INTRODUCTION

Among the many methodological issues with which an archeologist must be concerned on a recurring basis, sampling ranks high in importance. The issue of sampling is critical to the very nature of the study of prehistory because it relates to the archeologist's ability to make even elementary observations about many facets of the archeological record (Nance n.d.a). Similarly, a general trend toward quantification in the field has necessitated a focus on sampling problems. Thus, in recent years archeologists have become concerned with such things as representativeness of samples from site surveys (e.g., Schiffer, Sullivan and Klinger 1978), and estimation of regional archeological parameters through probabilistic sampling procedures (Mueller 1974, 1975; Nance 1979, in press a, in press b; Plog 1976, 1978; and others).

Most interest has focused on sampling at the regional level with little attention given to problems of site sampling other than to observe that site sampling is a complex issue. Mueller (1975) has considered site sampling operations and concludes that sampling of a three dimensional solid is necessarily a cluster sampling procedure. Redman (1975) has considered alternative sampling strategies for archeological sites while others (Brown 1975; Asch 1975; Morris 1975; Reid, Schiffer, Neff 1975) have addressed various individual topics. In this paper we present results of statistical examination of surface collection data from the lower Cumberland area of western Kentucky which are specific to problems of site sampling.

THE LOWER CUMBERLAND ARCHAEOLOGICAL PROJECT

Data for this study were collected during field work undertaken in 1978 as a part of the Lower Cumberland Archaeological Project. This project is a long-term study directed primarily towards investigation of the Archaic occupation of extreme western Kentucky (Fig. 2.1). Although the project has

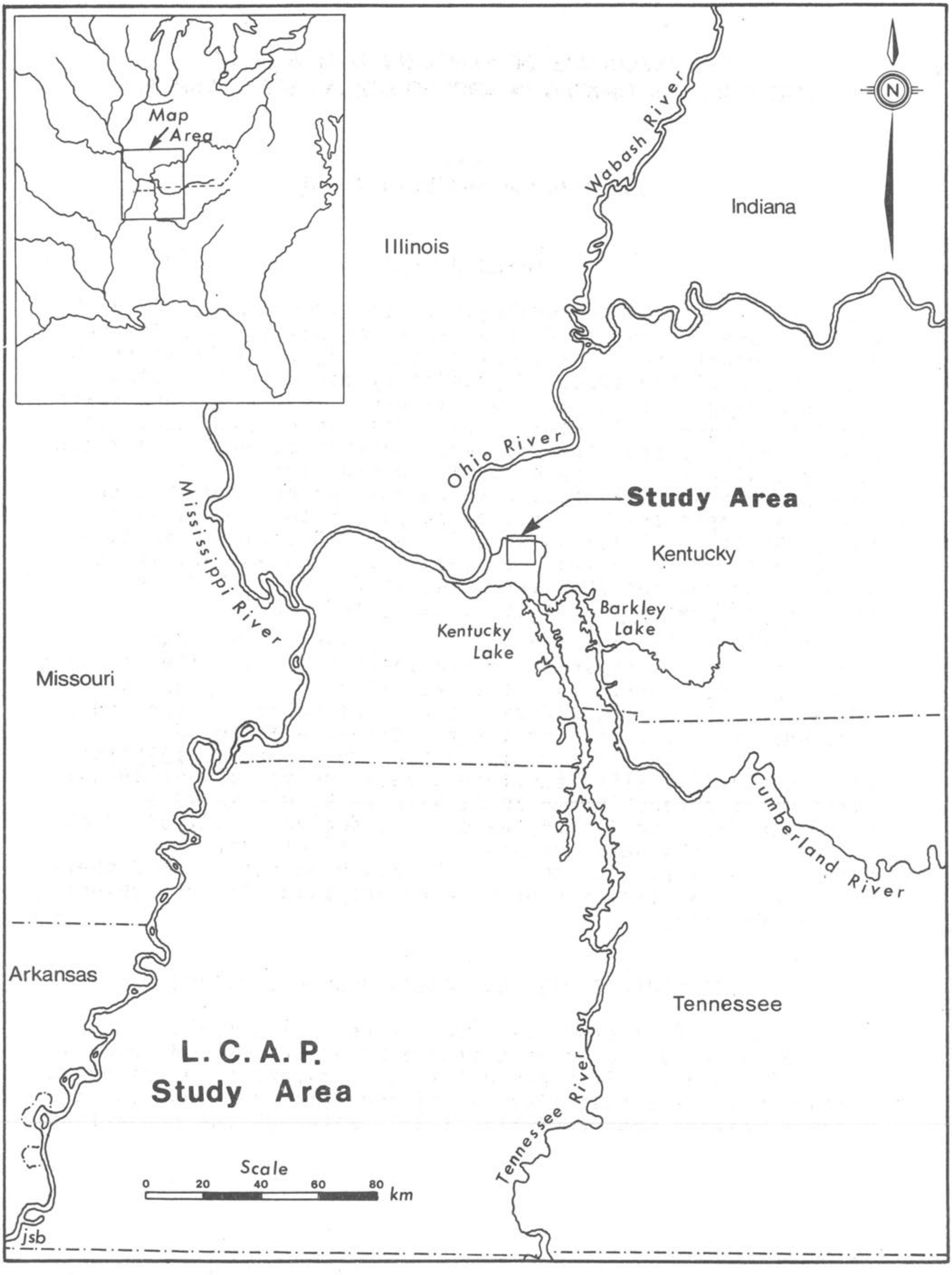

Figure 2.1. Location of Lower Cumberland archeological project study area.

diverse objectives (Nance, in press a) the main thrust involves an attempt to exploit the research potential of the many small, briefly-occupied campsites associated with Archaic manifestations in the region.

With respect to these small sites, it was reasoned that any attempt to study them collectively must include consideration of the adequacy of the methods used to assess their content. Investigation of the nature of most sites in the area (Nance n.d.a) suggests that use of probabilistic sampling is quite appropriate. That is, many of the small campsites are located in cultivated areas and are shallow (plowzone) deposits; it appears that in most cases the subsurface distribution of materials may be assumed to correspond, more or less, to the limits of cultural materials on the present land surface. With this assumption in hand it is proposed that a random sample of a site's present surface area will approximate a random sample of the total volume of the site. If these assumptions are supported, then the requirements for statistically valid sampling of the sites may be approximately met by superimposing a population of N grid units on the present site surface, randomly selecting n units from this population, and collecting cultural items by recovery of clusters of items from grid units. With these considerations in mind, quantities of surface locational data were systematically collected from several sites located along the lower Cumberland River flood plain to permit investigation of statistical sampling of these types of artifact accumulations.

Surface Collection and Data Processing

The inherent character of surface collections has yet to be fully documented. House and Schiffer (1975) and Baker (1978) suggest such phenomena as "size effect" to be of importance while Ammerman and Feldman (1978), using "replicated" surface collections, conclude that many factors, including surface conditions at the time of collection, soils, grid size, and overall density of materials in the site matrix, may influence the characteristics of surface collections. We are not concerned here with biases which inhere in surface materials. Rather, our interest centers on the use of surface collections to investigate the effect of variation in collection unit size, when the objective is to obtain precise estimates of statistical parameters relating to a population of cultural items.

The primary data collection strategy which we used in amassing data for this study involved intensive surface collection. In brief, this involved systematic survey of the site area, flagging all items present on the surface and taking the polar coordinates of these locations using a chain and transit. A more detailed description of this procedure is presented by Ball (1978).

Once we returned from the field, materials collected were cataloged and exact locational data for each item were entered in computer files. Subsequently, computer programs were used: (1) to convert the locational data to grid coordinates; (2) to place a grid matrix over site areas, using grid sizes from one to 12 meters square, and to determine the frequency of different item classes within each grid square; and (3) to calculate various statistical quantities (discussed below) for each item class at each grid size.

SAMPLING DESIGNS AND STATISTICAL ESTIMATION

As noted above, our interest in this study lies primarily in observing the effect of variation in collection unit size in archeological site sampling. Sampling procedures may be broadly classified in two categories: element sampling and cluster sampling. An element sample is one in which elements are selected independently; that is ideally the selection of one element for the sample does not influence the selection of any other element. In this design each sampling unit corresponds to one element available for selection and sampling unit size is not an issue. Clearly, when the population of interest is the total aggregate of cultural items within a site deposit, obtaining an element sample is not practical. Thus, site sampling normally proceeds by superimposing a grid, representing all possible excavation units, over the site surface and exploration of the site deposit takes place through examination of the content of n grid squares. Relative to the population of cultural items on the site, elements are collected in clusters, one cluster from each grid square.

To obtain an appreciation of the significance of the change in sampling design let us consider a hypothetical example. Suppose, for instance, that the objective is to estimate the proportion, p, of a total assemblage of obsidian artifacts. If an element sample can be taken, then the proportion of obsidian artifacts is estimated to be:

$$\hat{p} = x/n$$

where,

n = number of randomly selected artifacts and
x = number of obsidian items in the sample.

The predicted error of the estimate is:

$$s_{\hat{p}} = \sqrt{\hat{p}\hat{q}/n-1}$$

where $\hat{q} = 1-\hat{p}$. Thus the only quantities important in determining the precision of the estimate are the magnitude of p itself and sample size, potential error being inversely proportional to the latter. If, on the other hand, we select n grid units for investigation, we have n cluster samples at hand, each of which yields a single estimate of the proportion as shown below:

GRID UNIT (CLUSTER)	TOTAL NO. ARTIFACTS	NO. OBSIDIAN ARTIFACTS	PROPORTION OBSIDIAN
1	125	26	.21
2	102	23	.23
3	94	40	.43
4	142	42	.30
5	126	27	.21

We will not consider calculations involved in estimating error in this case (see Nance n.d.a; Kish 1967) but note only that in cluster sampling a number of factors have a potential influence on the expected error and/or potential bias of $\hat{p}$: (1) variation in the proportion from unit-to-unit, (2) average number of items per unit (cluster size), (3) variation in cluster size, (4) number of clusters (grid units), and (5) degree to which the item of interest (obsidian artifacts) tends to aggregate within units. Nance (n.d.a) has considered these factors; it is important to note here, however, that the number of grid units is probably of prime importance and that size of the grid units is common to all five of the variables listed above.

One way to evaluate the efficiency of a cluster sampling procedure is to compare the variability observed in a cluster sample with the expected variation based on simple random sampling (SRS) theory. This can be most elegantly accomplished through the relatively simple calculation and assessment of the "Design Effect" (DEFF.).

DEFF = Cluster sample var./Element sample var.

In the interest of time we will not go into detailed discussion of this quantity; extensive consideration may be found in Kish (1967:161-164). In general, however, this ratio will be 1.00 when the cluster sample variation equals SRS variation. A value less than 1.00 indicates uniformity in inter-unit variation; values greater than 1.00 indicate reduced efficiency for the cluster sample. In this study, DEFF was calculated over grid sizes from one to 12 meters for each item class occurring on the surface of five sites. The sites range in definable surface area from several meters in length and width to fairly large sites measuring 400 x 100 m. Artifact counts varied considerably from 25 items on the smallest site to about 1500 on the largest. With respect to the following, it must be emphasized that it is the behavior of DEFF which is being studied and not sampling unit content. Thus, the results have nothing to do with the co-occurrence of item classes within grid units. Rather, they describe the way DEFF varies for different item classes when grid units of progressively larger size are employed as collection units. As well, results are not subject to sampling error since calculations are based on total population of items on the site surface and total population of grid squares over the site surface. A considerable amount of data were generated; consequently, we concentrate on presenting regularities which are detectable in the results.

RESULTS

The least that can be said is that DEFF responds in a variety of ways to variation in grid size. The scatter-grams in Figs. 2.2, 2.3, 2.4 and 2.5 illustrate this. Grid size is shown on the abscissa and DEFF on the ordinate. Figure 2.2 provides an example of an apparently linear negative relationship while Fig. 2.3 depicts a positive linear relationship. Figure 2.4 is an example of a non-linear positive relationship and Fig. 2.5 shows a case where DEFF values appear very stable for low grid sizes but fluctuate wildly at larger unit sizes. We have not had an opportunity to fit curves to the accumulated data. Some patterning is, nevertheless, clearly indicated. Regardless of the type of function required to describe the points in a particular case, it is clear that at small grid sizes DEFF tends to be relatively stable, whereas at the larger grid values it varies considerably. This is an expected result in as much as larger grid sizes tend to reveal spatial clustering of items more than smaller sampling units (cf. Whallon 1973).

In an attempt to observe over-all trends in the variety of responses of the DEFF values we used principal components analysis (PCA). Data matrices of the grid and DEFF values were constructed for each of the sites wherein the rows and columns corresponded to grids and DEFF values respectively. Thus, each grid size constituted a case and DEFF for item classes 1, 2, ... $\underline{k}$ constituted the variable values. PCA was then performed to determine: (1) whether or not DEFF values for specific item classes tend to behave in similar ways, that is, exhibit communality in correlation; and (2) whether or not different grid sizes tend to behave in generally similar ways relative to DEFF values over all item classes. PCA procedure is described by Nie et al. (1975:478-487), Rummel (1970:338-345), and others. We did not rotate any of the resultant components to seek simple

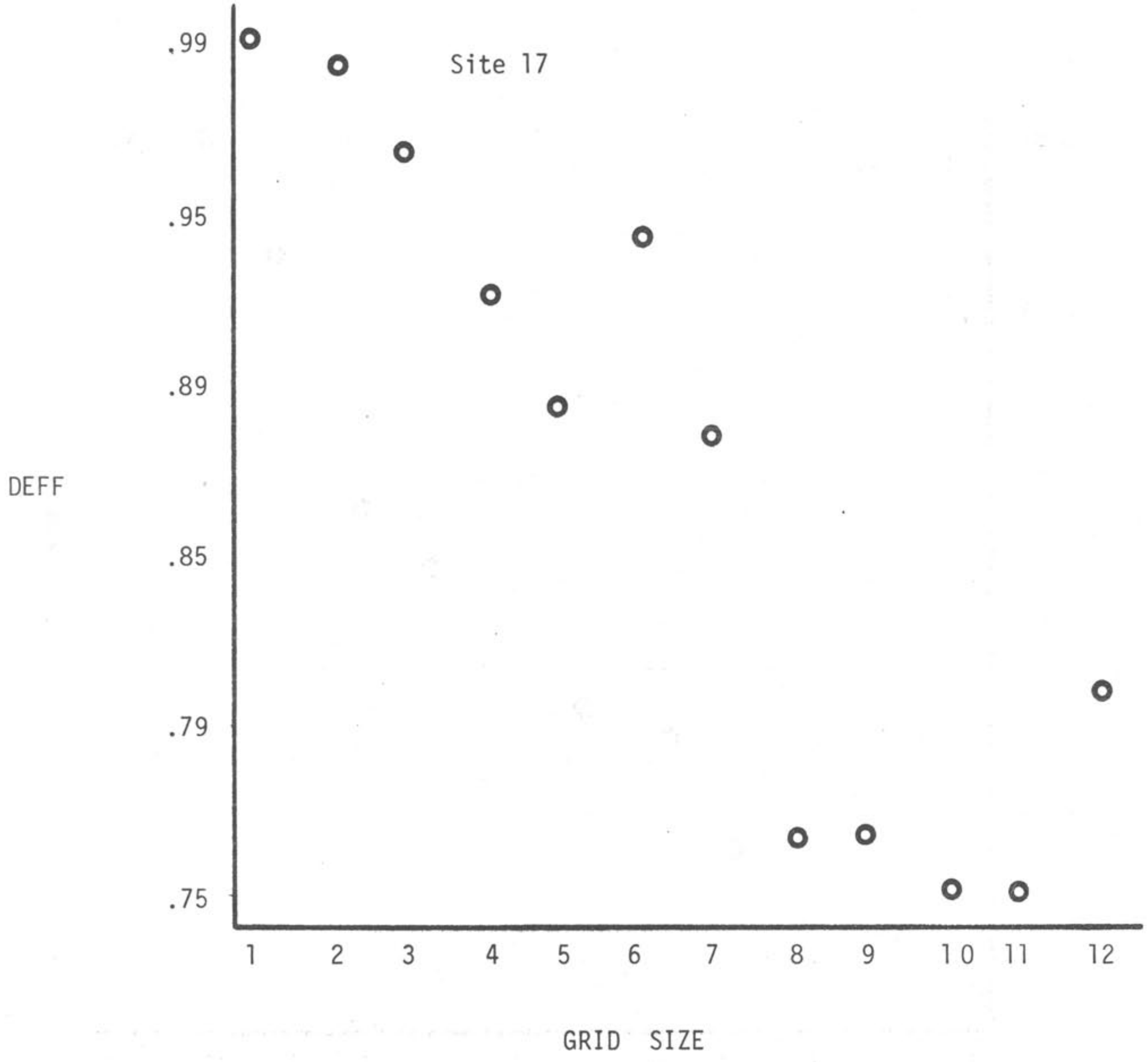

Figure 2.2. Relationship of DEFF to grid size, site 17.

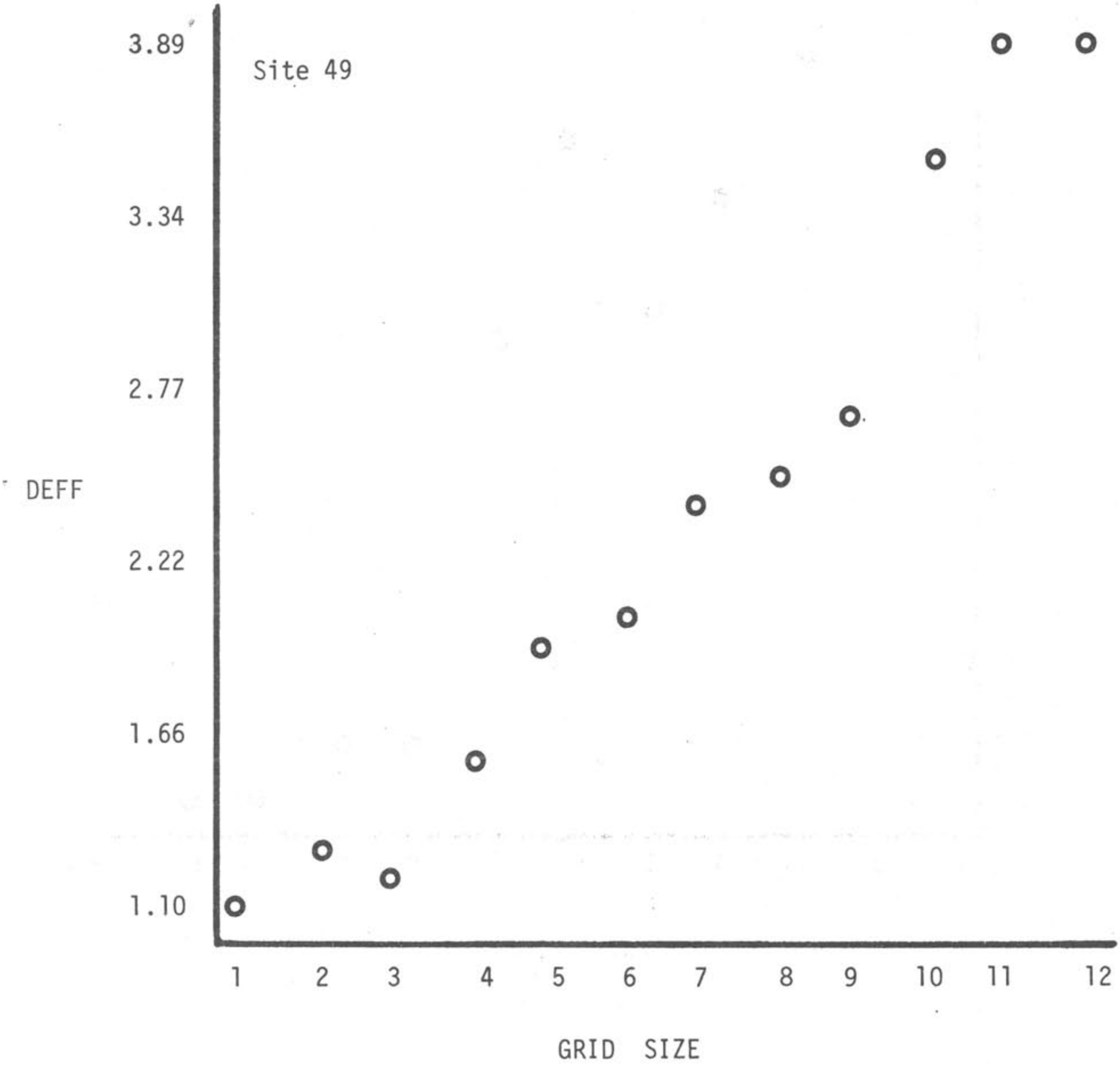

Figure 2.3. Relationship of DEFF to grid size, site 49.

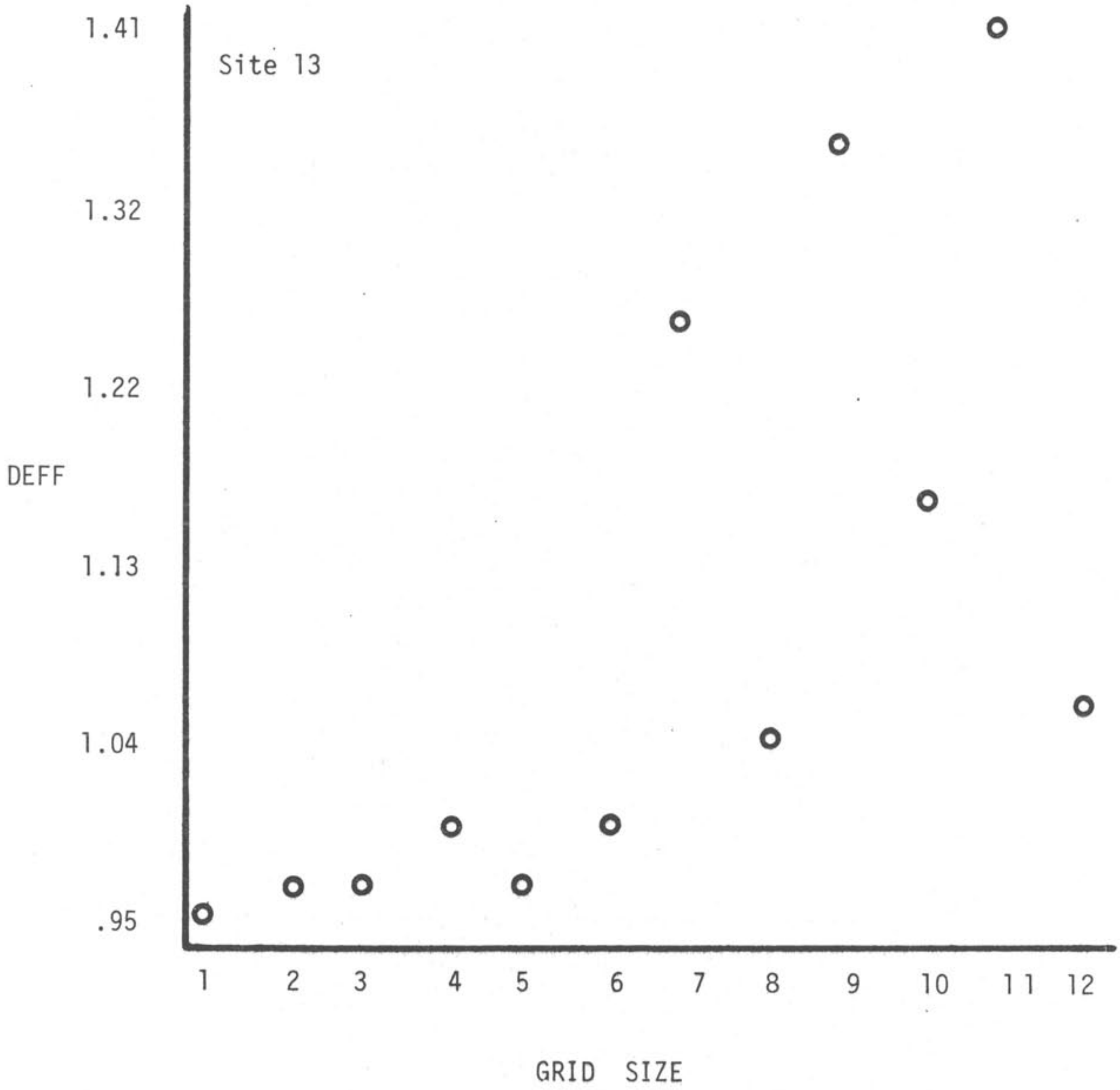

Figure 2.4. Relationship of DEFF to grid size, site 13.

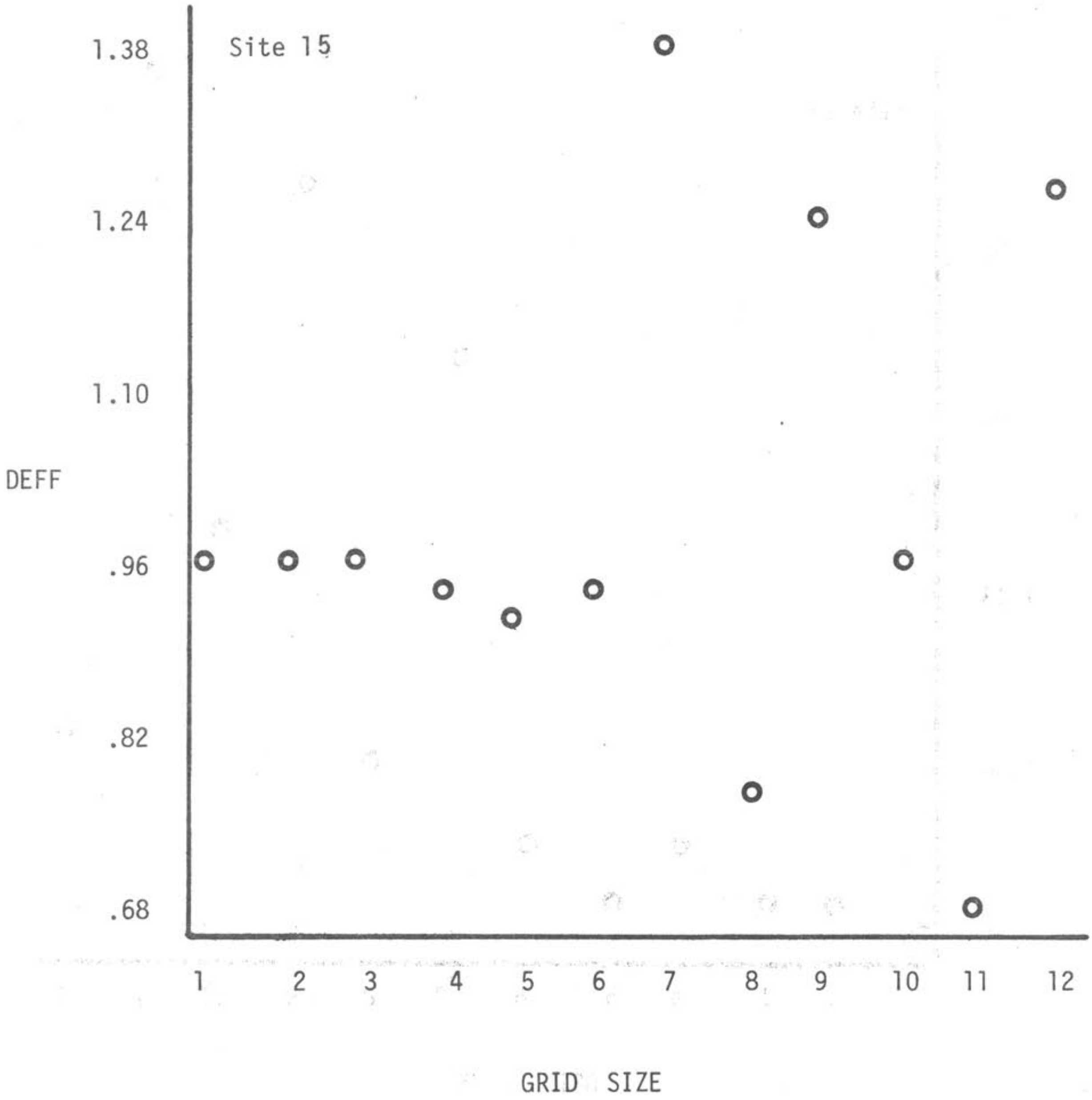

Figure 2.5. Relationship of DEFF to grid size, site 15.

structure; to retain simplicity here we only consider the first two components.

In general, PCA indicates that different item classes tend to exhibit correlated DEFF values over grid sizes since in all cases only a few components are sufficient to account for the majority of the matrix variance. Table 2.1, for example, shows that for two orthogonal components the minimum cumulative variance is 58.3% (Site 17), with first components accounting for 30.5% (Site 17) to 49.4% (Site 18). By nature of PCA the second component accounts for a smaller proportion of total variance.

Table 2.1. Cumulative Percentage Variance for Two Components.

SITE	COMPONENT 1	COMPONENT 2	TOTAL
13	30.85	29.63	60.48
15	40.97	30.92	71.89
17	30.45	27.87	58.32
18	49.36	17.17	66.53
49	47.91	20.73	68.64

Inspection of the scores for individual item classes on different components did not, however, indicate any consistent set or sets of item classes for which DEFF tends to behave in similar ways. This statement must be evaluated in light of the fact that there is some variety in the item classes which occur from site to site. Nevertheless, when cases, that is grid sizes, are projected onto components (Figs. 2.6, 2.7 and 2.8) considerable patterning is evident. In these diagrams points (grid sizes) which are located close together may be considered similar while those which are spatially separated tend not to be similar. "Similar" means "produced comparable DEFF values".

These results indicate that while there is marked variation in the item classes comprising individual components from site to site, certain grid sizes tend to behave similarly in terms of the DEFF values they produce. Specifically, smaller grid sizes tend to produce similar results while grid squares greater than about five meters square produce variable results.

However, analyses based on correlations only yield information on the pattern of the DEFF values and not their magnitude. Therefore, average values of DEFF were calculated for all item

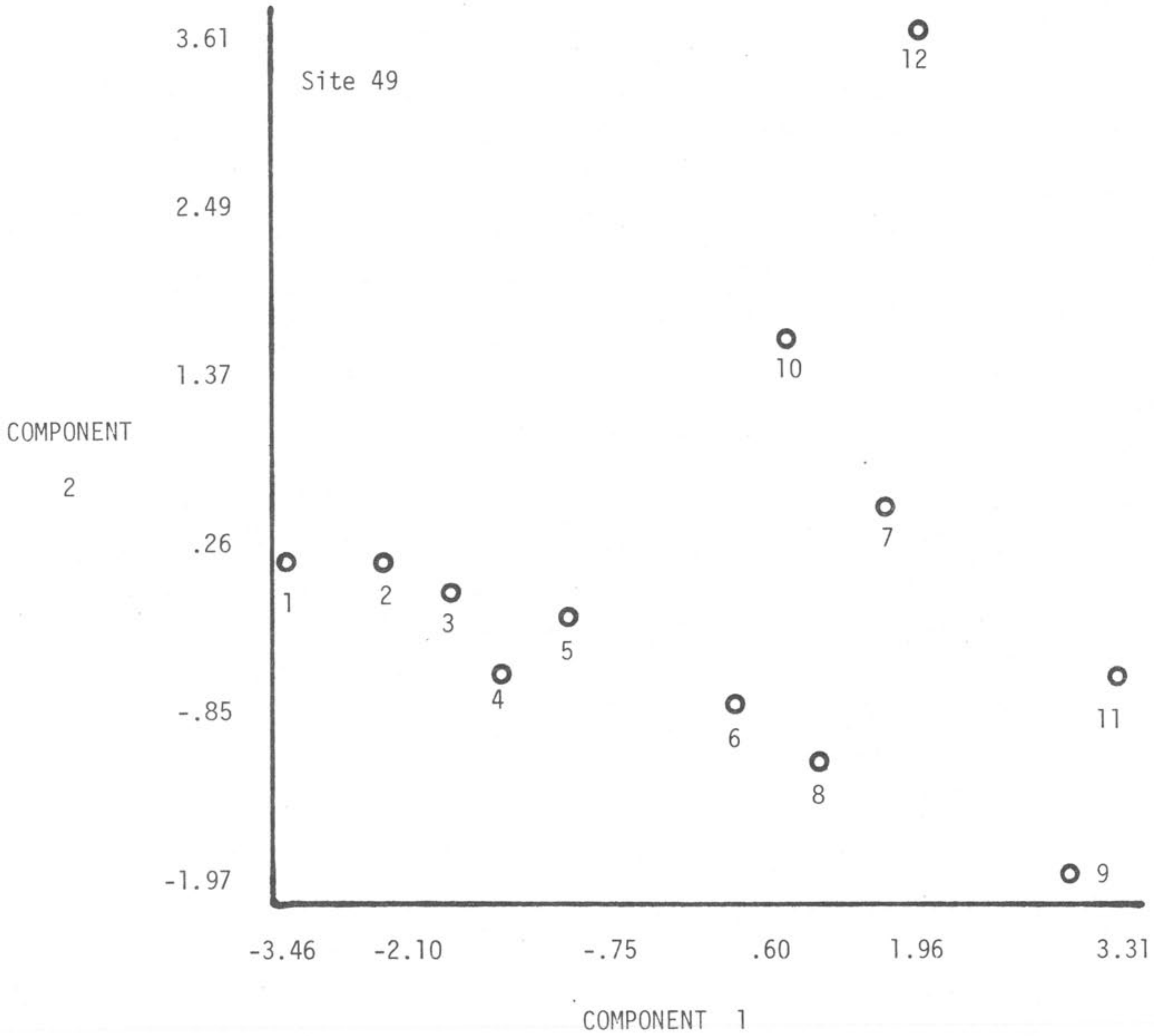

Figure 2.6. Principal components analysis of DEFF values and grid size, site 49.

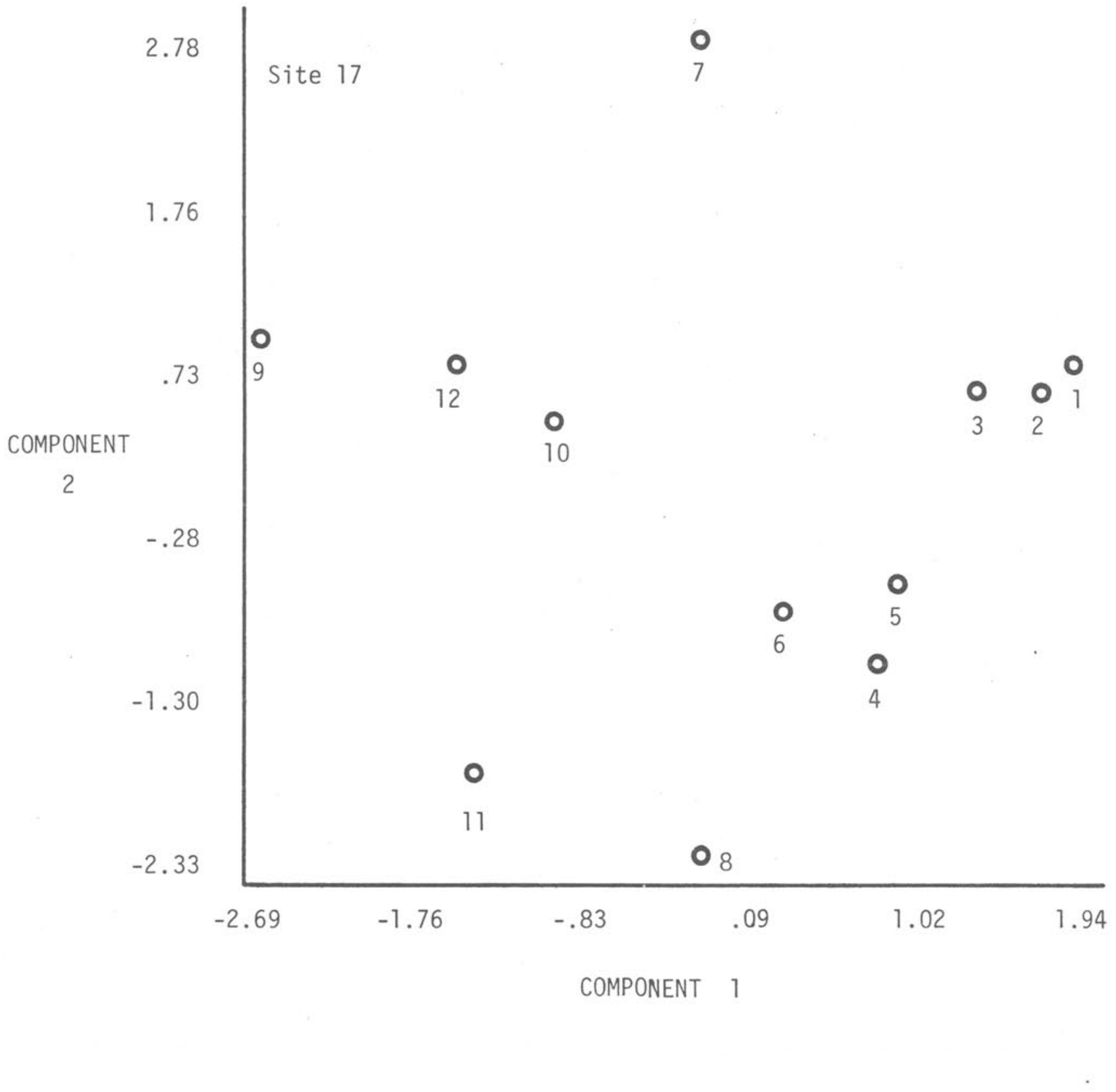

Figure 2.7. Principal components analysis of DEFF values and grid size, site 17.

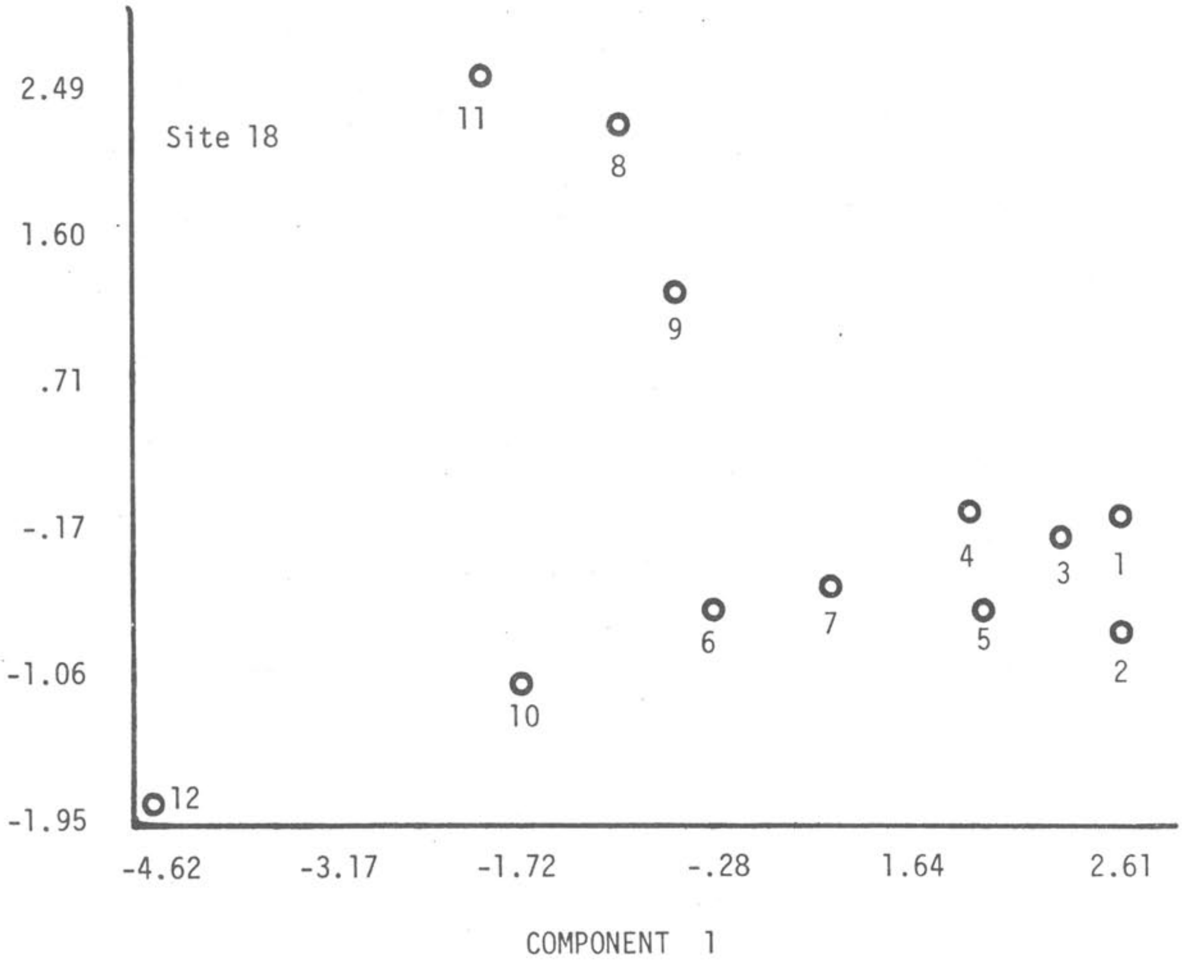

Figure 2.8. Principal components analysis of DEFF values and grid size, site 18.

classes over all grid sizes. These are shown graphically in Fig. 2.9. Clearly, the pattern which emerges is one of considerable variation as the size of the grid unit is increased.

CONCLUSIONS

Thus far, the results of this study clearly indicate three relatively valid predictions: (1) Design Effect should increase with grid size, on the average; (2) small grid units should generally produce lower values of DEFF and, therefore, yield more (statistically) efficient samples; and (3) small grid units also yield more consistent results than do larger ones.

At this point we feel it would be premature to attempt comprehensive generalizations because: (1) our research has been performed on a limited number of sites; (2) the surface collections analyzed do not, over all, contain large numbers of items; and (3) we have not had time to comprehensively consider the effects on DEFF which might be produced by extreme variations in item class frequencies. In addition, we feel it would be prudent to perform similar analyses utilizing item class taxonomies such as those suggested by Nance (n.d.b) and Schiffer (1972, 1976) which appear to be more appropriate to studies of cultural formation process.

Nevertheless, we can suggest general use of smaller sampling units when estimates of statistical precision are required. This somewhat cautious conclusion reveals that, fortunately, established archeological field methods are consistent with statistical reality; that is, most site sampling is currently accomplished using relatively small grid units. It must be noted, however, that in the majority of cases these grid units are not selected in statistically valid ways. Moreover, we feel that small grid units have other advantages since, in general, it can be argued that overall accuracy in data collection and fieldworker efficiency are enhanced by relatively small data collection units. These are considerations which should not be disregarded (cf. Clarke 1978). Finally, the preliminary findings presented here are encouraging in light of other possible problem areas, namely, the potentially detrimental effects of average cluster size, cultural item density and the like, on statistical precision in cluster sampling are reduced somewhat with the use of small data collection units (Nance n.d.a).

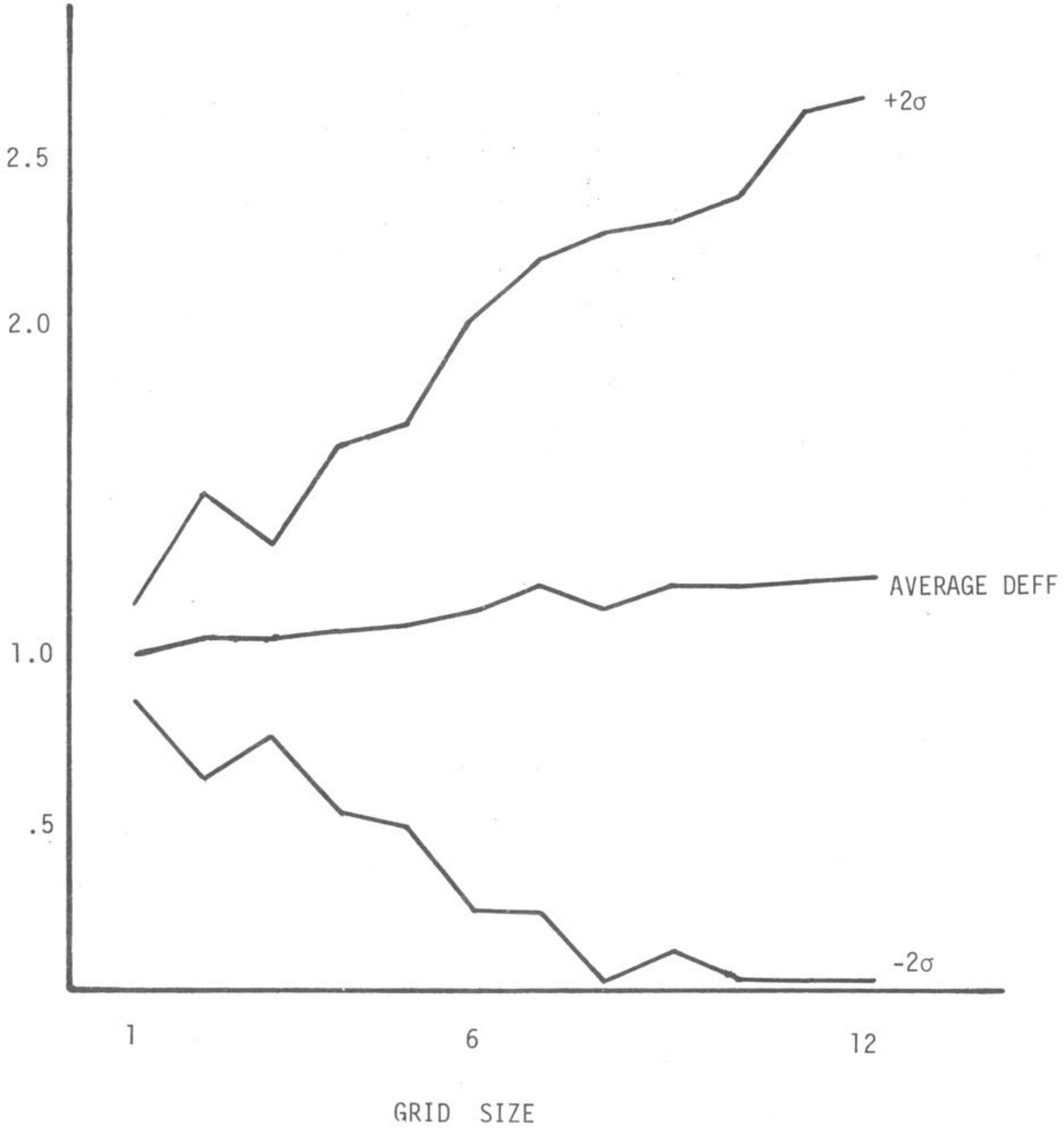

Figure 2.9. Relationship of average DEFF values to grid size.

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SURFACE COLLECTION AND ANALYSIS OF SPATIAL PATTERN: AN ARCHEOLOGICAL EXAMPLE FROM THE LOWER COLUMBIA RIVER VALLEY

by
Jerry V. Jermann

INTRODUCTION

During the past decade archeologists have become increasingly interested in analysis and interpretation of cultural patterns manifest in the locational aspects of artifactual remains. The consequent search for models and analytic techniques applicable to such studies has borrowed heavily from advances in human geography and quantitative plant ecology and has been accompanied by a quantitative revolution in the treatment of spatially disposed phenomena. While developments in the method and theory of cultural use of space show great promise for making significant contributions to studies of evolutionary patterns in cultural systems, these advances require a concomitant reassessment of the discipline's treatment of space as it pertains to data recovery. Most field strategies, which originally were developed for investigating culture historical problems, have as their primary goal collection of data with reliable temporal control. Although control of time always will be important to the discipline, these strategies may not provide reliable data concerning the spatial dimension of cultural variability. Characterization of spatial patterning requires adoption of field strategies that generate data with adequate referential control at the scale(s) of interest.

The current repertoire of available spatial analysis techniques can be divided into two general groups depending upon the degree of referential control required by each: nearest-neighbor analysis techniques, which require exact, three-dimensional control over the data of interest, and quadrat analysis techniques, which make use of counts for a planar study area divided into a grid of equal-sized cells. While the referential controls exacted by the two are decidedly different and have an immediate, important bearing on choice of field recording techniques, both share the need for recovery within a continuous expanse of space that is significantly larger than the cultural pattern of interest. This shared characteristic places a heavy premium on data recovery, particularly as it pertains to subsurface investigations.

Data collection by excavation is a decidedly labor-intensive strategy that may not be prudent or feasible in many circumstances. As an alternative strategy, systematic surface collection often can offer a means of gathering archeologically relevant data over a large continuous area with a minimal investment of time and labor. While surface-evident remains have long been used to guide subsurface investigations, their use as an independent source of data subject to detailed archeological treatment has been a relatively recent trend in the discipline. Given the prodigious growth of studies with a spatial perspective, however, surface collections should assume a much more important role in future data recovery strategies.

This paper details results of an intensive surface collection of a low-density archeological site, 45-SA-17b, located in the lower Columbia River valley of southwestern Washington. Funds to conduct necessary on-site investigations and later analyses were provided under a contract (DACW57-77-C-0099) to the Office of Public Archaeology at the University of Washington from the U.S. Army Corps of Engineers, Portland District, who were planning to use the area for a proposed park development. Earlier investigations of an adjacent land parcel had located the remains of a prehistoric site, 45-SA-17, that was largely confined to the surface. A similar situation was found at 45-SA-17b, and both the nature and spatial extent of cultural remains necessitated adoption of nontraditional data recovery and analysis techniques. The summary offered here, while a condensed version of the original contract report (Jermann 1978), illustrates the analytic and interpretive potential that can be realized as a consequence of controlled surface investigations.

Background

At the time of original investigations at 45-SA-17 in 1974, relatively little was known concerning aboriginal use of the Columbia River Gorge. This situation has changed markedly in the last few years. A series of archeological projects undertaken by and for the Corps of Engineers in the vicinity of Bonneville Dam in conjunction with construction of a second powerhouse at that facility has added significantly to our understanding of the region's prehistory (Dunnell and Lewarch 1974a; Dunnell, et al. 1976; Dunnell and Campbell 1977; Dunnell and Whitlam 1977). In almost all instances these investigations have been restricted to excavations carried out at large, artifactually dense domestic sites. While this has provided an in-depth picture of one important aspect of aboriginal subsistence-settlement pattern, much work remains to be done at smaller, low-density extractive sites before a complete record emerges.

The project area is situated approximately 1.6 km east of the confluence of the Wind and Columbia Rivers along what is now the north shore of Lake Bonneville, Skamania County, Washington. The closest community, the small settlement of Home Valley, lies 100 m to the north, just across State Highway 14 and the Burlington-Northern Railroad tracks (Fig. 3.1). Topographically, the project area is located on a former terrace of the Columbia River just east of a small stream that flows southward into the river. The terrace itself is characterized by a series of small hillocks and depressions formed in fine sands that extend to a depth of nine to 18 m to underlying andesitic and basaltic bedrock. Elevations in this area vary between 30 to 33 m above mean sea level.

Field work in anticipation of the proposed use of the terrace area as a recreational park began in mid-April, 1977, and was conducted intermittently until late in July of the same year. Similar archeological investigations had been undertaken by the Department of Anthropology at the University of Washington in 1974 at an area lying immediately to the west (Fuller 1974; Dunnell and Lewarch 1974b). Because the site which they describe, 45-SA-17, may be an extension of the cultural remains occurring in the current project area, we have arbitrarily designated the site 45-SA-17b.

Previous investigations in the immediate vicinity have detailed the environmental setting of the project area, and the reader is referred to those studies for more in-depth considerations of this topic. However, the entire terrace area containing evidence of prehistoric and historic occupation has been used for pasturage and has witnessed repeated plowing. Aerial photographs of the area taken around the time of construction of Bonneville Dam indicate that the western portion of the site also may have been used for an orchard.

The Field Recovery Program

Data recovery techniques employed in assessing 45-SA-17b to a large extent parallel those used in investigation of cultural remains at 45-SA-17 (Dunnell and Lewarch 1974b): systematic surface collections from the site area following mechanical plowing and disking. This general technique was chosen over controlled archeological excavation because it offered the best opportunity of maximizing potential information gain within the financial and temporal constraints of the proposed park development. A cursory reconnaissance of the project area indicated that while cultural remains could be found scattered over the entire area scheduled for development, their density was even lower than that reported for 45-SA-17.

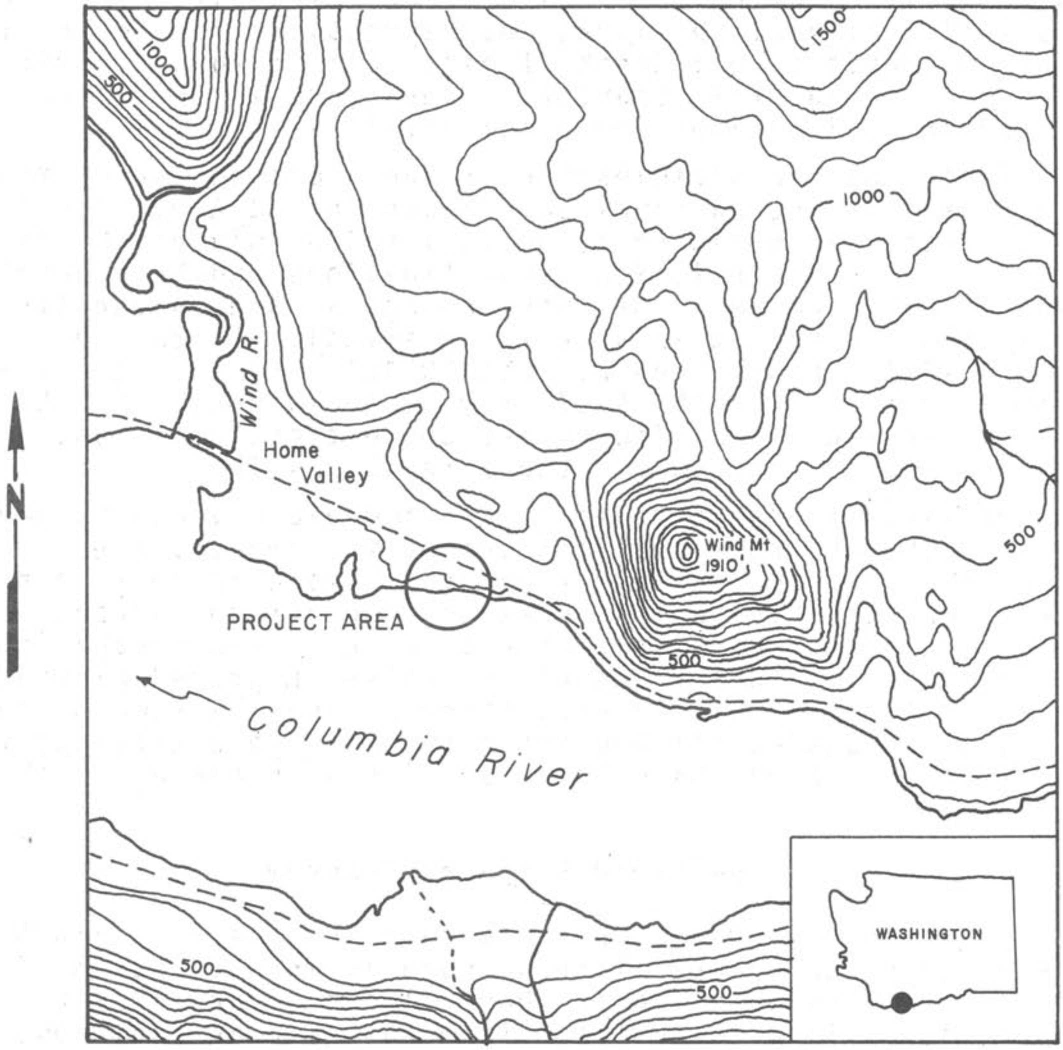

Figure 3.1. Vicinity map of project area.

Even in the unlikely event that surface-evident remains could have been used to choose a "representative" spatial sample, excavation could have provided information about only a relatively insignificant percentage of site area. Systematic surface collection offered a means of generating comparable referential data over a much larger area with substantial labor savings.

Following a brief pedestrian reconnaissance of the project area, which served to substantiate the presence of cultural remains, efforts were directed towards recovering a sufficient artifact sample to characterize the functional and temporal structure of the area. The initial recovery step consisted of systematically collecting all surface-evident materials. The field team carefully examined the ground surface and noted all larger than sand-sized objects using nails flagged with surveyor's tape. Systematic coverage was provided by having personnel walk along parallel transects spaced less than one m apart. This procedure was undertaken twice to insure that no objects were overlooked. The decision to identify all larger than sand-sized objects was twofold. First, the soil matrix over the project area is characterized by sands and silts. Thus, any larger-sized object could potentially owe its location to artificial origin, i.e., be identified as an artifact. Second, the technique also precluded making on-site determinations of whether a given object was cultural. By eliminating artifact recognition from the purview of the surveyor, field recovery could proceed with a minimum of collector bias.

Each object flagged during reconnaissance subsequently was collected and its two-dimensional horizontal location recorded by measuring by transit each "artifact's" radial distance and angular orientation from an arbitrary site datum located along the western periphery of the project area (Fig. 3.2). Recovery within an arbitrary grid was not felt to be warranted in view of the low artifact density and the difficulties of choosing an appropriate size collection unit without prior knowledge of the potential scale of artifact patterning. Collecting materials within too small a grid unit would have unnecessarily increased recovery time and probability of recording error, while recovering materials within too large a grid size would have obscured spatial patterning.

The systematic surface collection described above resulted in the recovery of only 80 objects within an area of approximately 37,500 m^2. While low artifact density could be attributed to the mitigating influences of extant vegetation cover (pasture grasses), the problem remained of having too small a sample to adequately characterize the site. Although repeated surface collections might have increased the number of objects in the sample, there still was little hope that the resultant assemblage would provide an adequate basis for analysis. Alternative measures

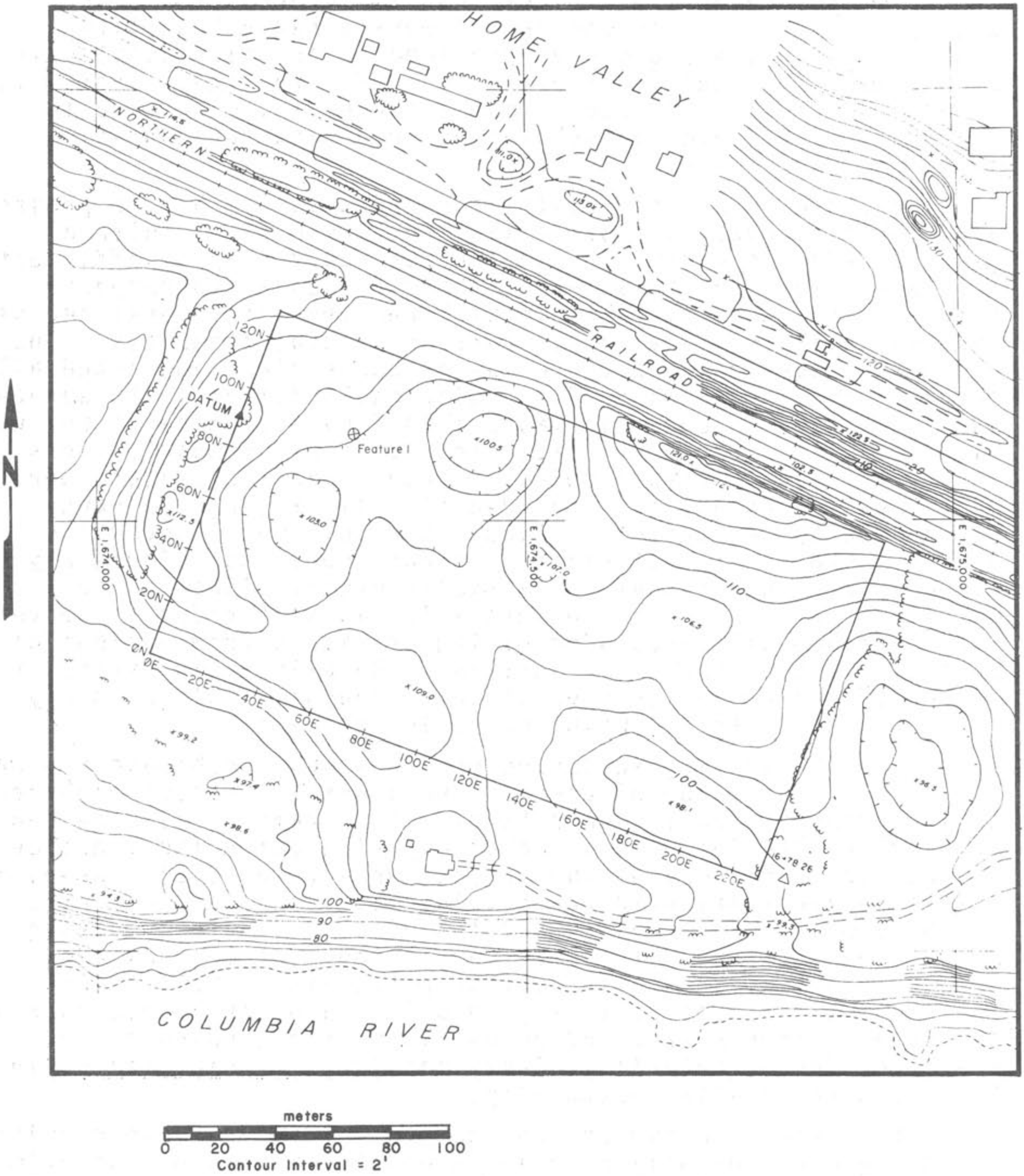

Figure 3.2. Location of project-related features with respect to the general vicinity.

were necessary. In view of its prior success at 45-SA-17, an artificially prepared surface was created by plowing. It should be stressed that while plowing in some circumstances might potentially destroy or significantly affect archaeological site integrity, such was not the case here. Indeed, the potential archeological benefits to be derived from this activity far exceeded any possible loss of spatial coherence.

Following preparation of the site's surface, the entire area again was examined for evidence of cultural remains. Field reconnaissance procedures duplicated those used in the initial surface collection. Surface conditions were ideal: the absence of a heavy root mat, the sandy soil, and the occurrence of a heavy rainfall following plowing provided a uniform surface plane. Recording of object-specific referential data did vary, however, from that described previously. Two surveyor's transits located a known distance apart were used to record the angular orientation of each object from a north-south baseline established over the arbitrary site datum. The resultant pair of angular measurements for any given object can be transformed into Cartesian grid coordinates using well-known geometric relationships. For example, given two known points (e.g., transit stations), A and B, on a Cartesian plane, coordinates for an unknown point can be calculated as follows (see Fig. 3.3):

$$x = \frac{m_2 x_2 - m_1 x_1 + y_1 = y_2}{m_2 - m_1}, \text{ and}$$

$$y = m_1 (x - x_1) + y_1,$$

where $m_1 = \tan \underline{a}$ and $m_2 = \tan \underline{b}$. This technique is neither overly complicated nor labor-intensive. Necessary computations to perform coordinate transformations are relatively simple and easily adapted for use with a programmable calculator or digital computer. Far from being labor-intensive, on-site collection and recording required substantially less time than would have been needed to collect the same objects within a grid system. Given the added benefit of gaining data with known coordinate locations, the technique has much to recommend it.

Data recovery following preparation of the ground surface by plowing was substantially greater than that achieved following initial reconnaissance. More than 600 individual objects were recovered from the plowed surface, almost an eight-fold increase over the previous collection.

Finally, the entire plowed surface of the site was mechanically disked and recollected. Field identification and recording procedures duplicated those used previously. Despite two previous intensive surface collections, post-disking recovery was remarkably high; more than 750 objects were collected from the disked surface.

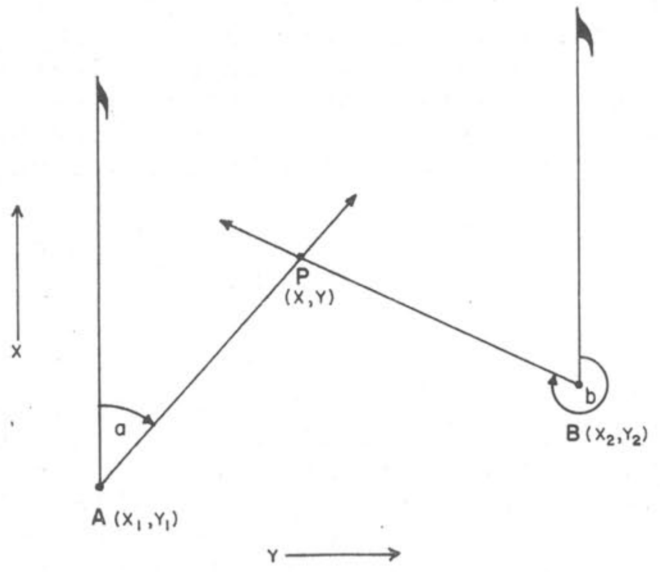

Figure 3.3. Diagrammatic representation of triangulation referential method.

Before taking up consideration of the spatial distributions of material remains recovered from 45-SA-17b, certain observations and conclusions can be made concerning the conduct and results of field recovery efforts. Obviously, there are significant differences in sheer quantities of material remains recovered within the context of the three independent surface collections (Table 3.1). The most important conclusion to be drawn from the results of various recovery procedures is that merely collecting objects from an unmodified surface would have led to a highly biased, grossly underrepresented sample of this site's assemblage. This is not to imply that plowing and/or disking should be applied universally as surface-preparatory techniques. Indeed, such measures probably should not be used in instances where the post-occupational surface has not been plowed previously or, more generally, where the surface has remained relatively free from cultural or natural modification.

As a means of assessing possible biases in cultural assemblage content arising solely as a consequence of surface condition, a series of histograms has been prepared that show the distributions of lithic weights recovered during the collections. As Fig. 3.4 clearly shows, site surface treatment has an important effect upon the frequency distribution of lithic weight. With each succeeding surface collection, not only are the mean and median weights of lithic objects reduced, but also the frequency curves tend to more closely approximate a Poisson distribution. Variability in distributions can, in part, be attributed to the cumulative but differential loss of available objects from a finite "artifact pool" lying within the upper 20 to 30 cm of the site's soil profile. The downward trend in the average size of objects from successive collections follows a logical progression. That the assemblage from the "unmodified" surface has the greatest mean and median weights per object is not at all surprising. Although this area had been plowed and disked previously, many years had elapsed since the last episode. During the intervening years, it is likely that smaller items became covered by humus from decaying grasses and soil from aeolian deposition and/or slope wash, rendering a surface assemblage characterized by larger-sized objects.

Removal of this segment of the available artifact pool disproportionately lowers the number of available larger-sized objects while having virtually no effect on the vast majority of cultural remains. Plowing has the effect of dramatically increasing area available for inspection by breaking up the surface plane into a multitude of much smaller-sized soil matrix surfaces. Thus, it is reasonable to expect that the average size of objects recovered after plowing should be significantly less than that manifest by an unmodified surface, and it is. The trend becomes even more pronounced after disking.

Table 3.1. Comparison of Recovery Rates from Various Surface Preparation Techniques.

MATERIAL CATEGORY	SURFACE CONDITION			
	UNMODIFIED	PLOWED	DISKED	TOTAL
FIRE-CRACKED ROCKS	n = 19	n = 19	n = 243	n = 453
	$\bar{x}$ = 580.8	$\bar{x}$ = 137.6	$\bar{x}$ = 64.9	$\bar{x}$ = 117.2
	m = 381.1	m = 43.0	m = 28.1	m = 36.5
	sd = 757.4	sd = 227.5	sd = 113.9	sd = 249.5
	sk = 2.59	sk = 3.00	sk = 4.53	sk = 6.12
	k = 8.23	k = 10.33	k = 27.62	k = 58.34
PEBBLES/ COBBLES	n = 30	n = 298	n = 315	n = 643
	$\bar{x}$ = 704.4	$\bar{x}$ = 142.4	$\bar{x}$ = 53.5	$\bar{x}$ = 125.1
	m = 345.2	m = 48.0	m = 20.8	m = 35.8
	sd = 1112.0	sd = 302.9	sd = 116.9	sd = 351.2
	sk = 2.92	sk = 5.09	sk = 6.34	sk = 8.01
	k = 9.87	k = 32.86	k = 47.71	k = 89.68
SLABS	n = 6	n = 25	n = 22	n = 53
	$\bar{x}$ = 938.5	$\bar{x}$ = 574.6	$\bar{x}$ = 355.3	$\bar{x}$ = 524.8
	m = 357.4	m = 408.6	m = 39.4	m = 302.2
	sd = 1075.7	sd = 622.6	sd = 597.4	sd = 683.7
	sk = 1.72	sk = 1.72	sk = 1.95	sk = 1.83
	k = 2.93	k = 2.80	k = 2.66	k = 3.06
MODIFIED LITHICS	n = 23	n = 72	n = 94	n = 189
	$\bar{x}$ = 252.9	$\bar{x}$ = 155.5	$\bar{x}$ = 74.4	$\bar{x}$ = 127.0
	m = 4.8	m = 19.4	m = 4.4	m = 7.1
	sd = 370.9	sd = 247.0	sd = 200.7	sd = 250.4
	sk = 1.14	sk = 1.86	sk = 4.46	sk = 2.51
	k = -0.15	k = 2.66	k = 22.99	k = 6.23
TOTAL	n = 78	n = 586	n = 674	n = 1338
	$\bar{x}$ = 559.1	$\bar{x}$ = 160.9	$\bar{x}$ = 70.4	$\bar{x}$ = 138.5
	m = 289.6	m = 46.6	m = 21.4	m = 34.0
	sd = 872.8	sd = 307.2	sd = 174.8	sd = 336.8
	sk = 3.11	sk = 4.17	sk = 6.33	sk = 6.42
	k = 12.13	k = 23.20	k = 49.74	k = 62.69

n = sample size; $\bar{x}$ = mean; m = median; sd = standard deviation; sk = skewness; k = kurtosis.

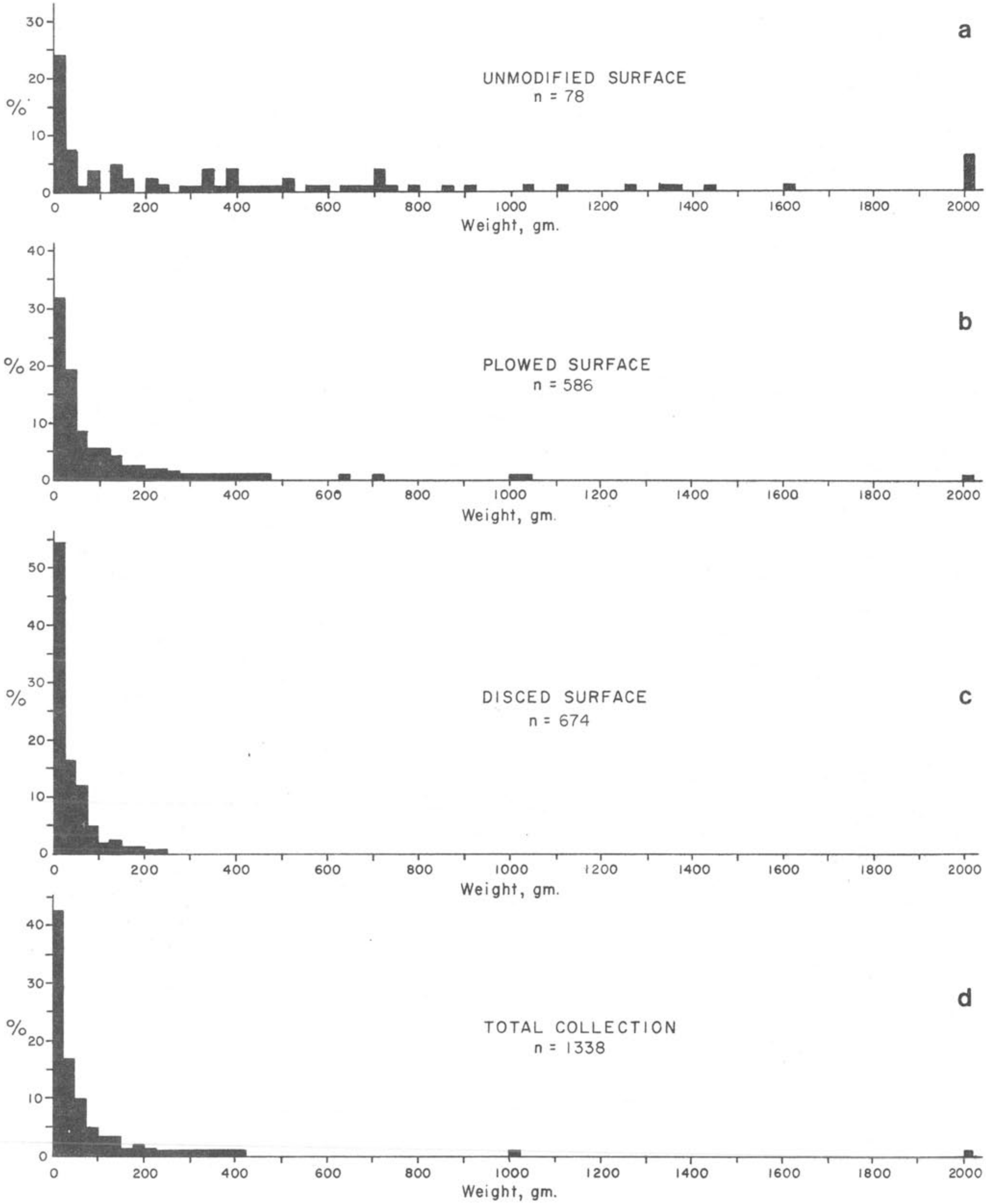

Figure 3.4. Comparative histograms of lithic weight for the three site surface treatments and the total collection.

Again, this can be attributed to reductions in number of available larger-sized objects and to further increases in surface area available for inspection by the disaggregating effects of disking.

Given significant observed differences in mean sizes of objects recovered in the three surface collections, no one assemblage should be viewed as representative of the entire site. Instead, the three assemblages taken in toto form the best indicator of available material inventory at this location. For this reason, most of the subsequent discussion of 45-SA-17b's cultural remains and their spatial distributions focuses on the total artifact assemblage.

DISTRIBUTIONAL RELATIONSHIPS

Despite the fact that archeologists traditionally have devoted significant proportions of their field investigations to careful and controlled recording of referential information, more often than not this aspect of the archeological record is all but ignored during analysis. When spatial variability has been treated, its horizontal, two-dimensional characteristics often are sacrificed at the expense of examining variation in vertical dimension. This preoccupation with undimensional variability is a direct outgrowth of the discipline's concern with describing and explaining temporal aspects in its site-situated data. Analytically, horizontal information is coalesced such that variability is restricted to a vertical perspective: sites are treated much as if they were layered points on the cultural landscape. Within this type of analytic framework, it makes little difference whether assemblages to be compared are products of a single test excavation or complete removal of a site, so long as sample sizes are adequate for statistical comparisons. Explication of horizontal variability/pattern often is relegated to subjective descriptions and conclusions based on plots of structural features (e.g., hearths, post molds, etc.). Even in the best of treatments, we often can expect only to be presented with plots of individual artifact locations within such features and subjective reconstructions of their cultural meaning. Much of the time and labor consumed in the preservation of locational information, one hallmark of modern archeology, seemingly is used to facilitate production of "pretty pictures." Although this might seem to be an overly harsh characterization, one will be hard-pressed to find a better explanation by examining the extant literature. This does not mean, however, that archeologists should abandon recovery of detailed referential data. This information is crucial to any reasoned reconstructive effort. Nevertheless, it cannot and should not be viewed as an end, but rather, as a means to such ends.

The last several years have witnessed the emergence of more objective methods to assess spatial dispersion and pattern of archeological data (Whallon 1973, 1974; Dacey 1973; Brose and Scarry 1976). While these efforts have been largely descriptive (i.e., directed towards deriving a summary statistic capable of characterizing a given spatial pattern) and have relied heavily upon parallel concerns in quantitative plant ecology and human geography, they do, nonetheless, represent some of the first serious attempts by archeologists to come to grips with spatial aspects of past cultural remains.

Because care was taken in the recovery of artifactual remains at 45-SA-17b to record the three-dimensional provenience of every object, we have sufficient information to avail ourselves of the full range of spatial analytic techniques. This is of some potential importance. As Brose and Scarry (1976), and others, have demonstrated, techniques which require exact two-dimensional coordinates for each artifact may not yield the same results as those that require only grid counts. In this case we can apply both kinds of techniques and compare the outcomes for internal consistency and replicability with the ultimate goal of gaining a better understanding of the spatial properties of the assemblage.

Non-manipulative Mapping

Upon conclusion of field activites, we were confronted with several hundred objects collected from the site's surface and by a corresponding list of referential information necessary to relocate the coordinate position of each object. A FORTRAN program for use on the University of Washington's CDC 6400 computer and CalComp plotter was developed to transform a given object's angular coordinates into Cartesian grid coordinates and plot the resultant location onto a contoured base map of the project area. The latter was generated by an NPS (Numerical Plotting System) library subroutine requiring a filled rectangular/square grid of $\underline{x}$ and $\underline{y}$ values and an associated functional ($\underline{z}$) value, such as elevation, for each grid crossing. In this instance, the elevational grid derives from a transit survey of the project area surface over an imaginary 10 m grid. The program initially was used to examine differences among the three intensive collections taken under varying surface treatment conditions. The resultant plots are presented as Figs. 3.5 to 3.8.

The differences previously noted among the three surface collections in terms of object size are even more marked in terms of spatial dispersion. Materials collected from the unmodified surface are not only significantly fewer in overall number, but also are generally confined to the central and lower

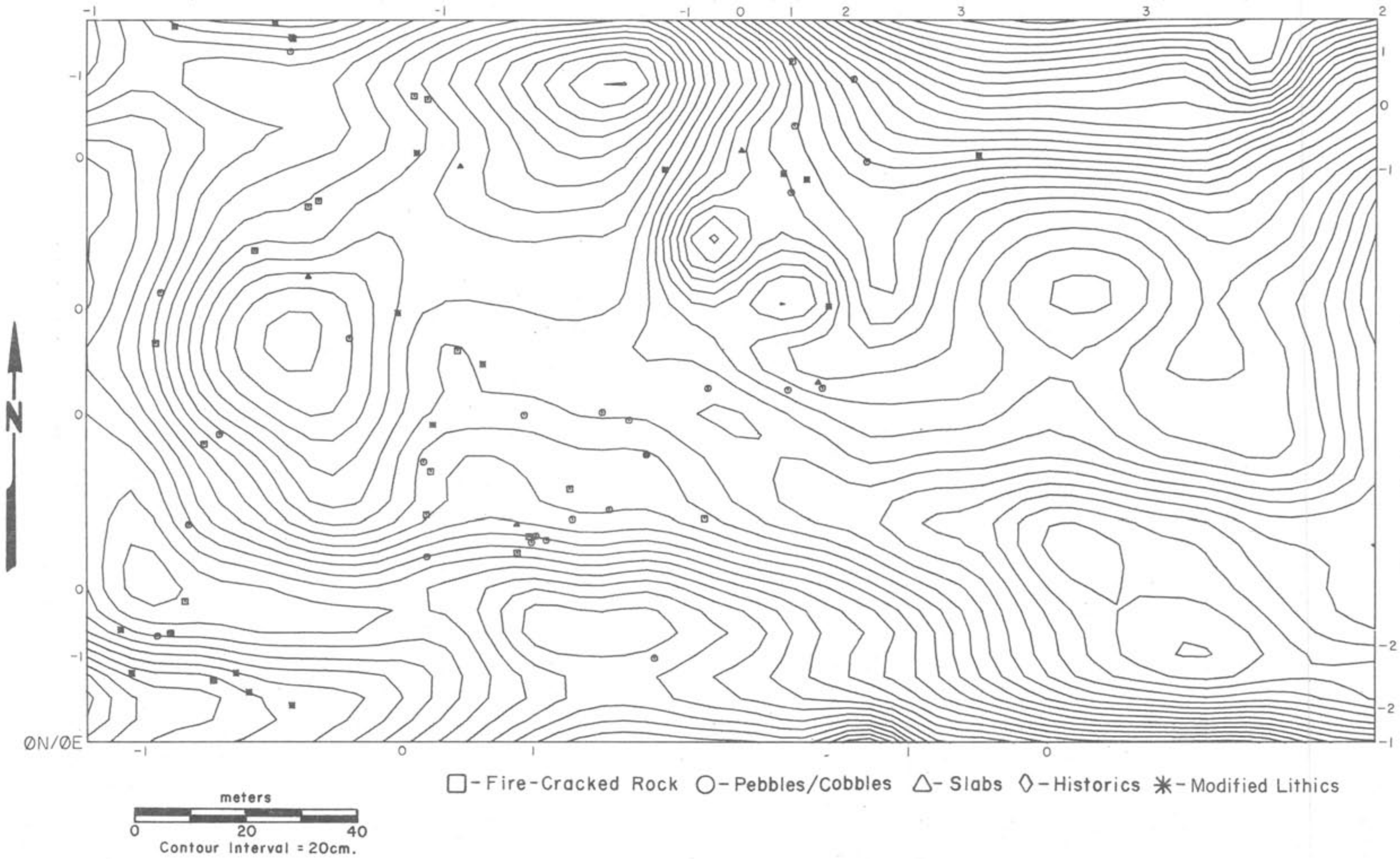

Figure 3.5. Distribution of general assemblage categories resulting from collecting an unmodified surface.

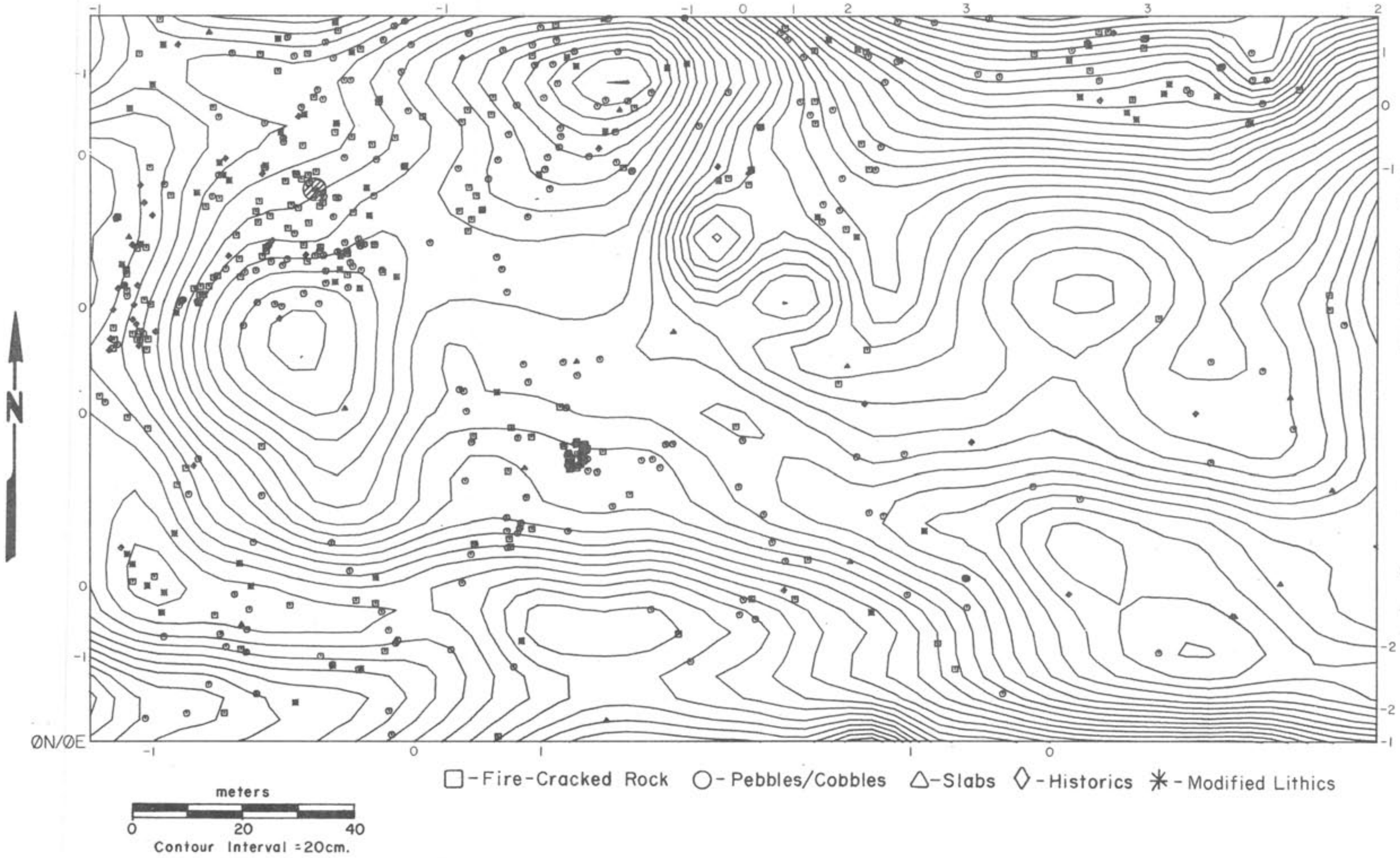

Figure 3.6. CalComp plot of post-plowing distribution of general artifact assemblage.

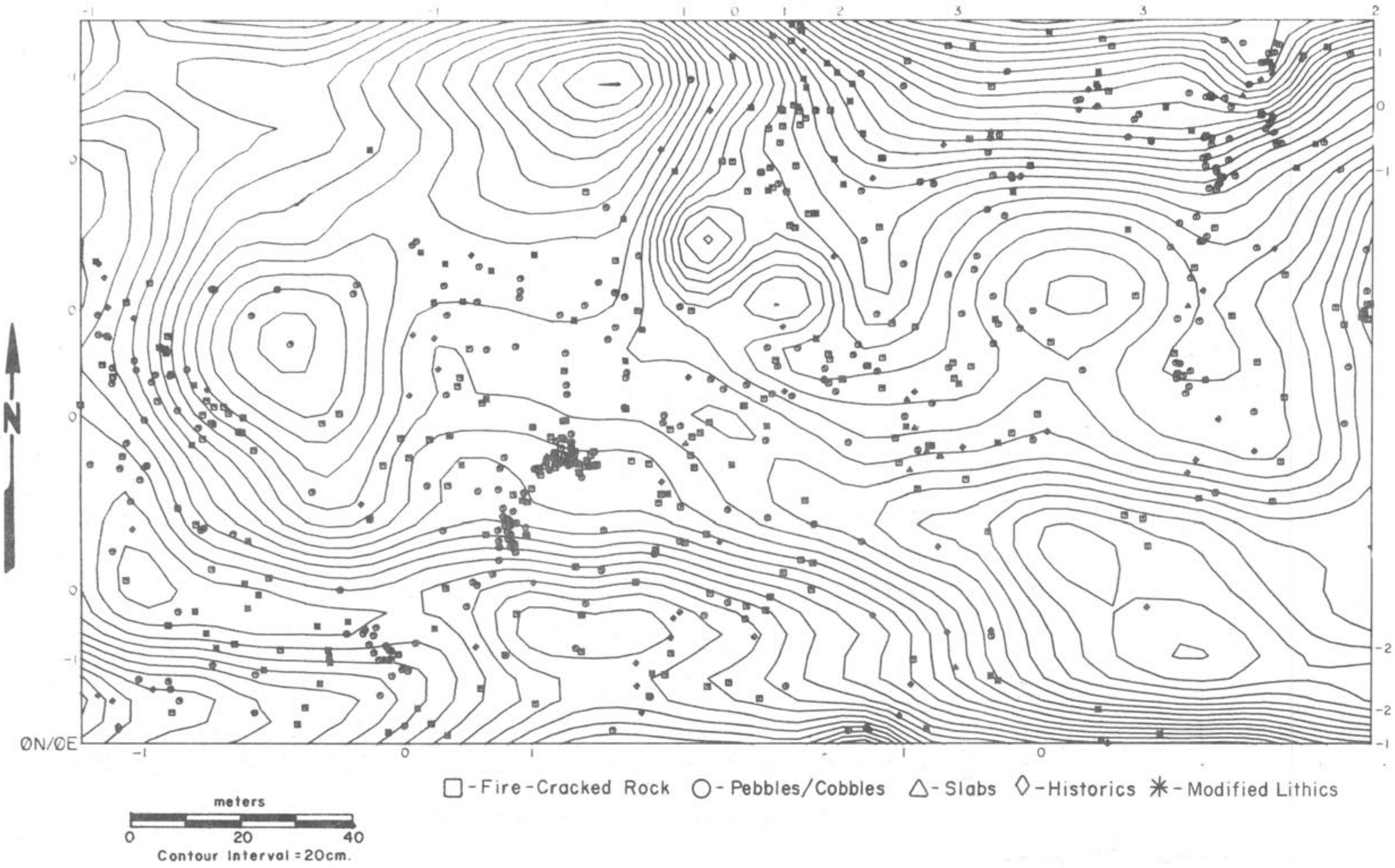

Figure 3.7. CalComp plot of post-discing distribution of general artifact assemblage.

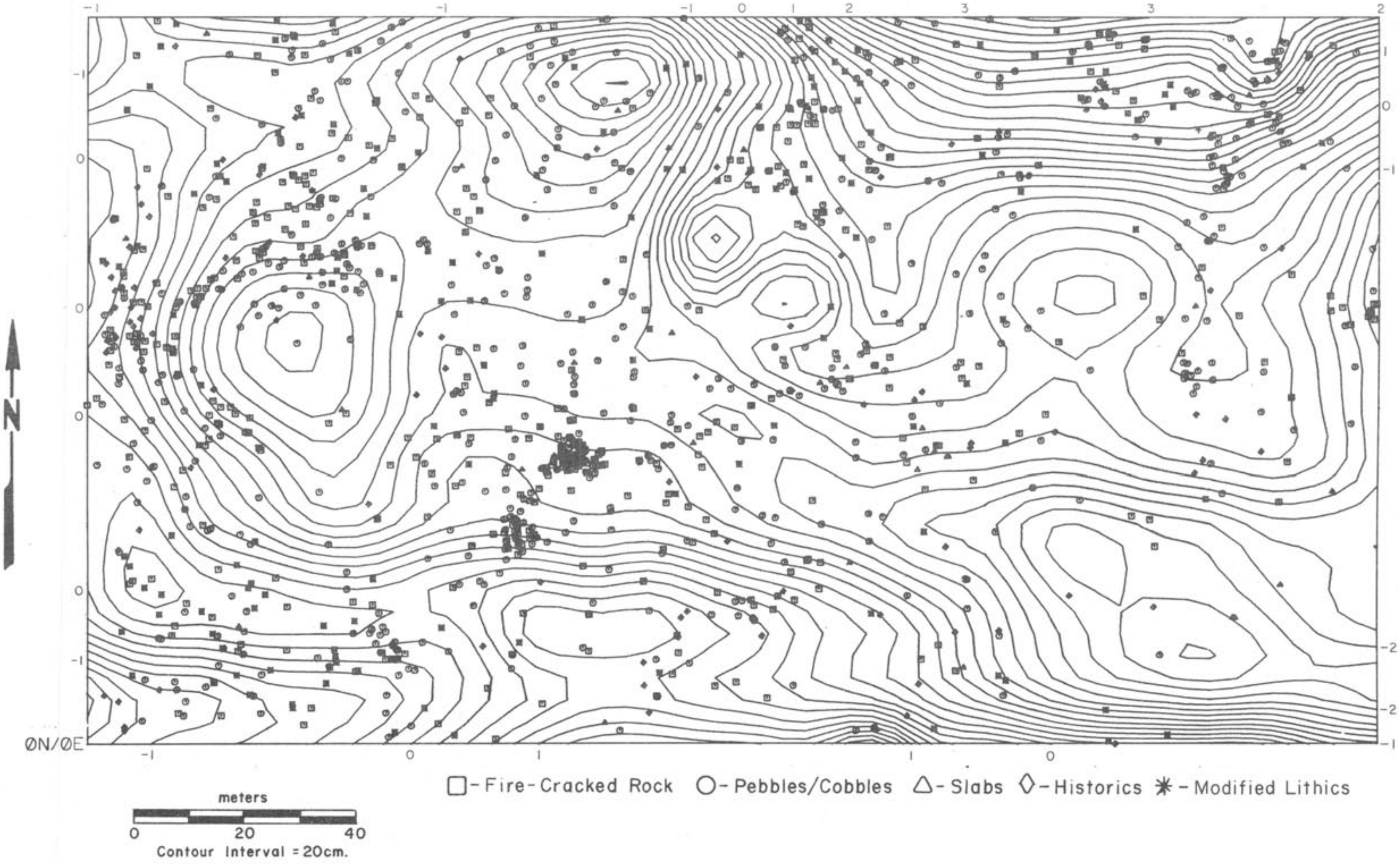

Figure 3.8. CalComp plot of general artifact assemblage from all surface collections.

slopes of major hillocks occurring within the project area (Fig. 3.5). These also correspond to those portions of the site exhibiting sandier soil deposits. Such a spatial pattern seems consistent with probable effects of long-term exposure. In more silty or clayey soil matrices, there would be a tendency for precipitation to "puddle" and subsequently obscure the surface, and colluvial sediments would tend to accumulate between hillocks and thus bury any artifactual remains. Additionally, aeolian action along the tops of the uniformly sandy, dune-like hillocks could serve to either accumulate or remove particulates. The difference between sandy and silty soils is particularly evident in the plots for the post-plowing (Fig. 3.6) and post-disking (Fig. 3.7) collections. The northeast portion of the site is characterized by much sandier soils. From the maps it is apparent that post-plowing recovery rates are considerably higher in sandy soil. Again, this is consistent with what we might anticipate. Sandy soils are much less cohesive and consolidated than silty ones and therefore can be broken more easily by a plow. Silty soils could be expected to require more intensive mechanical preparation to render optimal exposures, and this is confirmed by the spatial dispersion of the post-disking collection. Recovery is significantly lower on sandier soils (probably a consequence of the loss of objects from the available artifact population pool following the post-plowing collection), but markedly higher on siltier surfaces.

The above observations lend further credence to the previous decision to consider the sum total of all three surface collections as the most valid indicator of spatial dispersion of the cultural assemblage. For this reason all further discussion will be restricted to observations based on the total surface collection (Fig. 3.8).

As a means of further examining spatial dispersion within the site assemblage, a series of maps has been produced depicting the distributions of each of four major assemblage constituents. Fire-cracked rock (Fig. 3.9) seems to display two kinds of dispersions: a component manifest as rather tightly clustered patches occurring at various locations along narrow terrace-like features or upper and mid-slopes of hillocks, and another component manifest as a more random dispersion occurring over the entire project area. Those portions of the site that exhibit clusters of fire-cracked rock probably represent loci of former domestic activities involving heating and/or cooking. Somewhat surprisingly, distribution of unmodified pebbles/cobbles (Fig. 3.10) is highly coincident with that of fire-cracked rock. It was initially felt that the presence and distribution of these objects may have been a result of natural rather than cultural processes. However, the marked co-association of the two classes suggests that a significant number of pebbles/cobbles represent objects that were used in heating/cooking activities but were not fire-cracked.

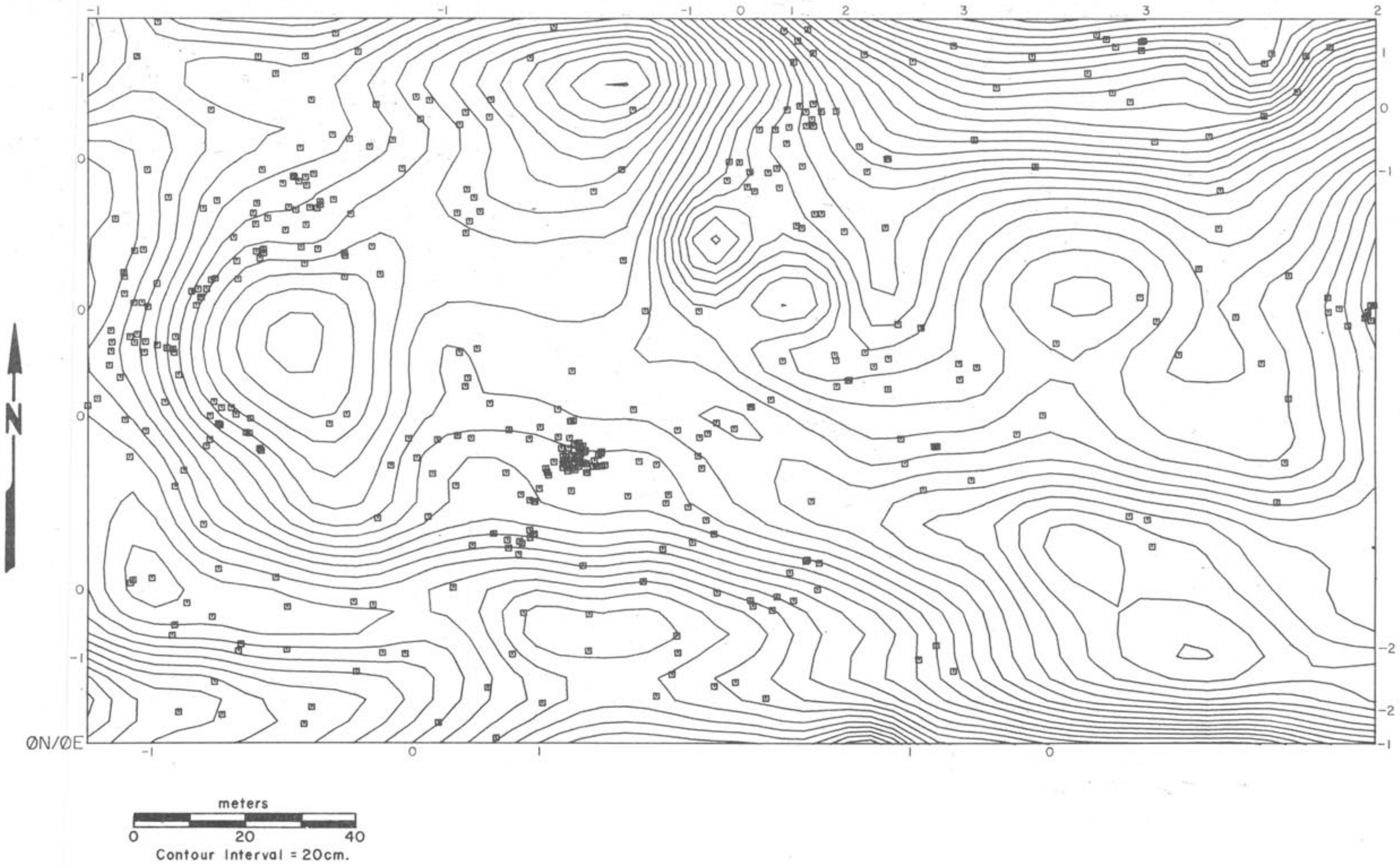

Figure 3.9. CalComp plot of fire-cracked rock occurring in contour grid area.

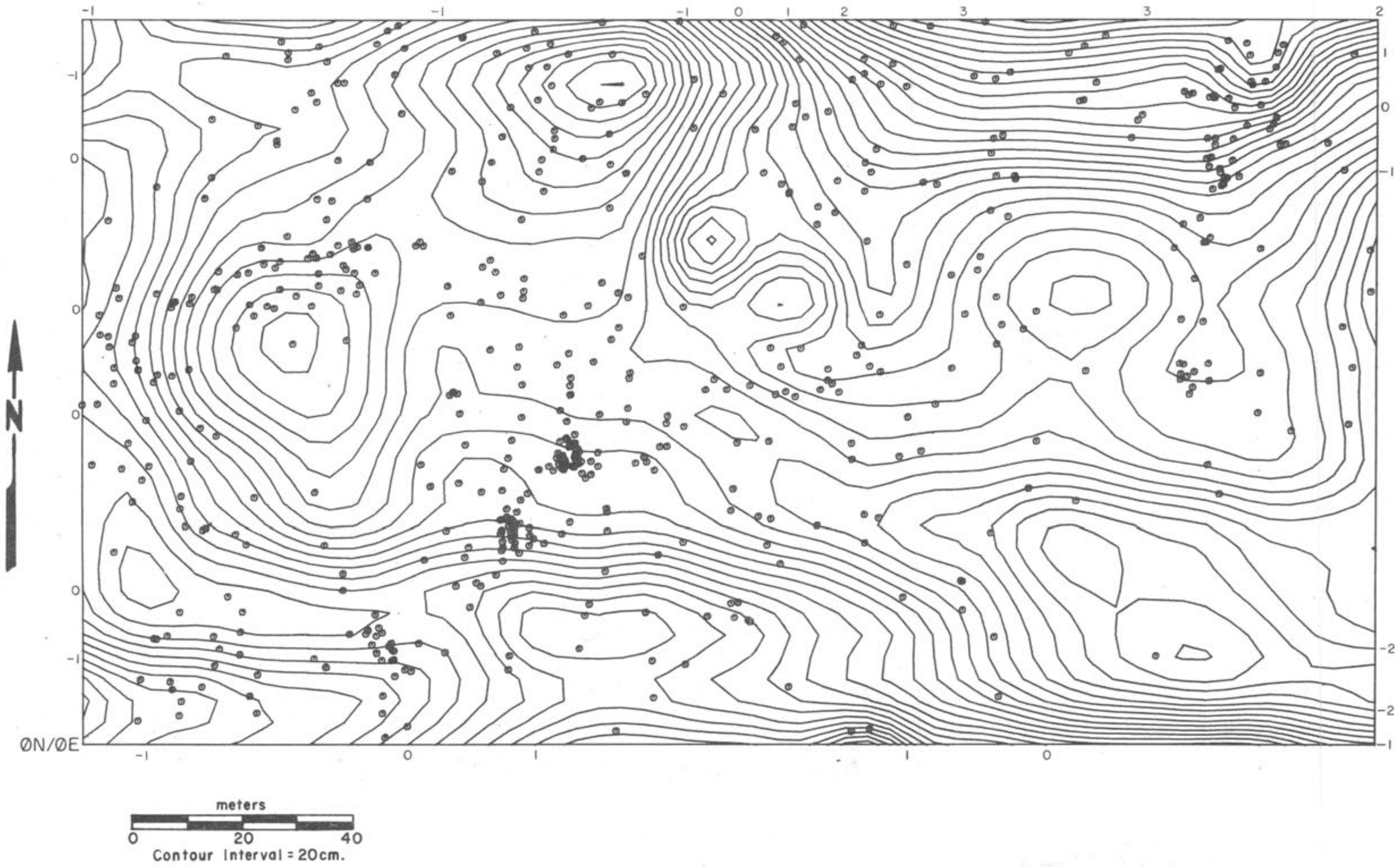

Figure 3.10. CalComp plot of pebbles/cobbles occurring in contour grid area.

Basaltic slabs (Fig. 3.11) display two localized spatial clusters as well as a highly dispersed distributional component. One of the clusters is immediately adjacent to a dense concentration of fire-cracked rock and pebbles/cobbles and therefore may be associated with whatever activity took place there. The other cluster occurs somewhat to the east and is not coincident with any other concentrations of material. Because of the small number of objects in this cluster, its occurrence may be entirely fortuitous and more easily explained as being part of a generally random dispersion that characterizes this material component.

Modified lithic material occurs in several dispersed clusters (Fig. 3.12). Interestingly, these "clusters" generally occur around the immediate periphery of concentrations of fire-cracked rock and pebbles/cobbles. Such a contiguous distribution lends additional support to the earlier conclusion that fire-cracked rock and pebbles/cobbles are associated with prehistoric cultural activities. The internal spatial structure of this constituent of the assemblage cannot be explicated further within the framework of a simple plot of artifact location. As a means of examing this aspect of spatial patterning, distributions of the most frequently occurring functional classes, including projectile points, were plotted (Fig. 3.13). The results are less than definitive, as none of the functional types other than non-utilized objects occurs in clusters. There is, however, a tendency for heavy core tools (e.g., cobble choppers) and tools on otherwise unmodified objects (e.g., hammerstones) to be concentrated in the northern half of the collection tract. Even so, this pattern is neither clear-cut nor altogether informative. Given the low density of material remains comprising this aspect of the assemblage, it is possible that activity areas at this site may be manifest by single co-occurrences of a limited number of tool types. However, such associational patterns are difficult to isolate even under optimal circumstances. In the current instance, comparatively large distances between individual tool objects further lowers the potential utility of such an analysis.

IDENTIFICATION OF SPATIAL PATTERNING

While spatial distribution maps of various components of an artifact assemblage provide a highly visible means of displaying precise dimensional relationships both within and between individual classes, their interpretation in the absence of independent data must come from subjective judgments based on simple inspection. If we are to derive inferences concerning the meaning of spatial patterning in prehistoric site assemblages, it is necessary to attempt to put such considerations on more objective grounds. Fortunately, this concern has attracted in-

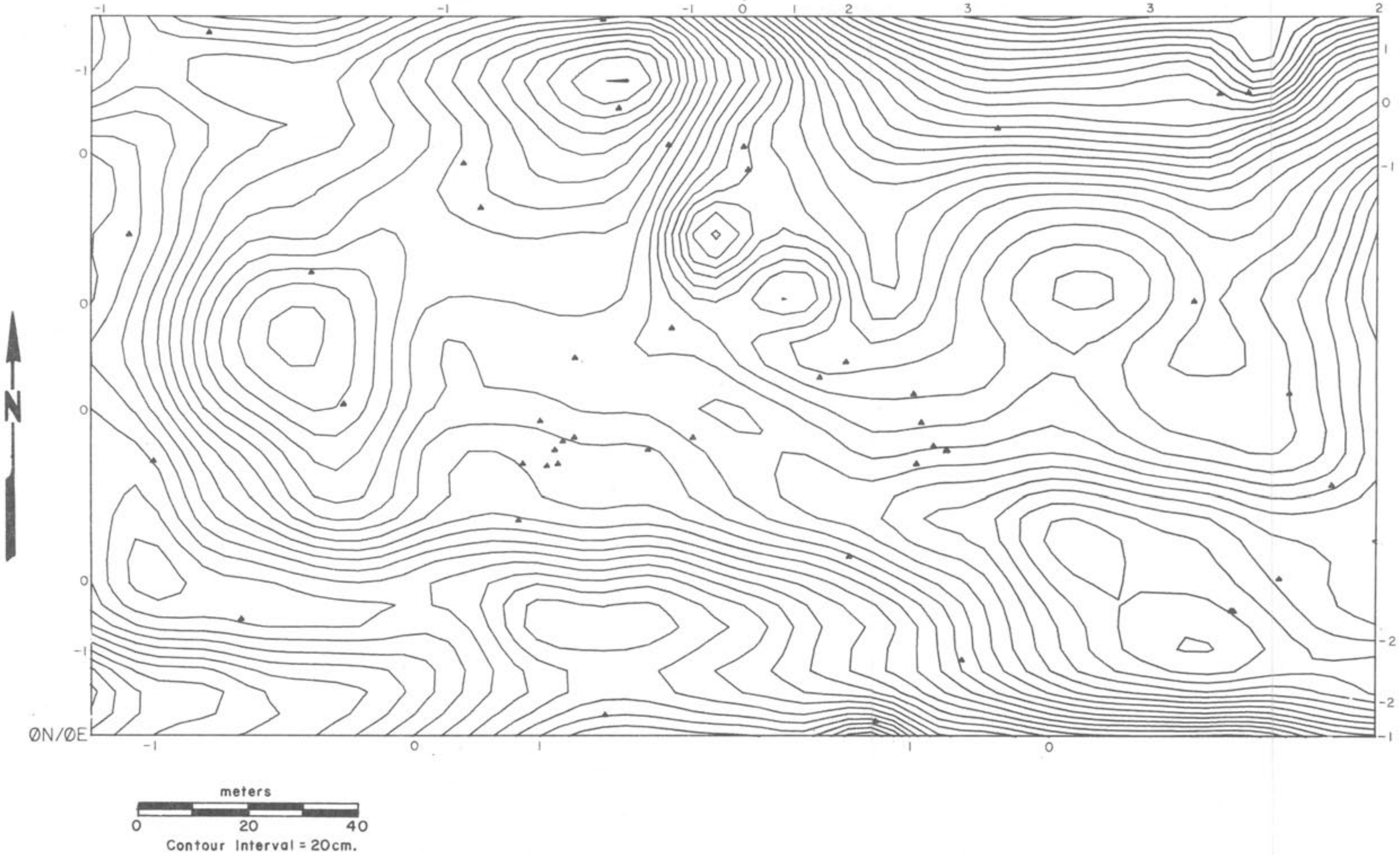

Figure 3.11. CalComp plot of basaltic slabs occurring in contour grid area.

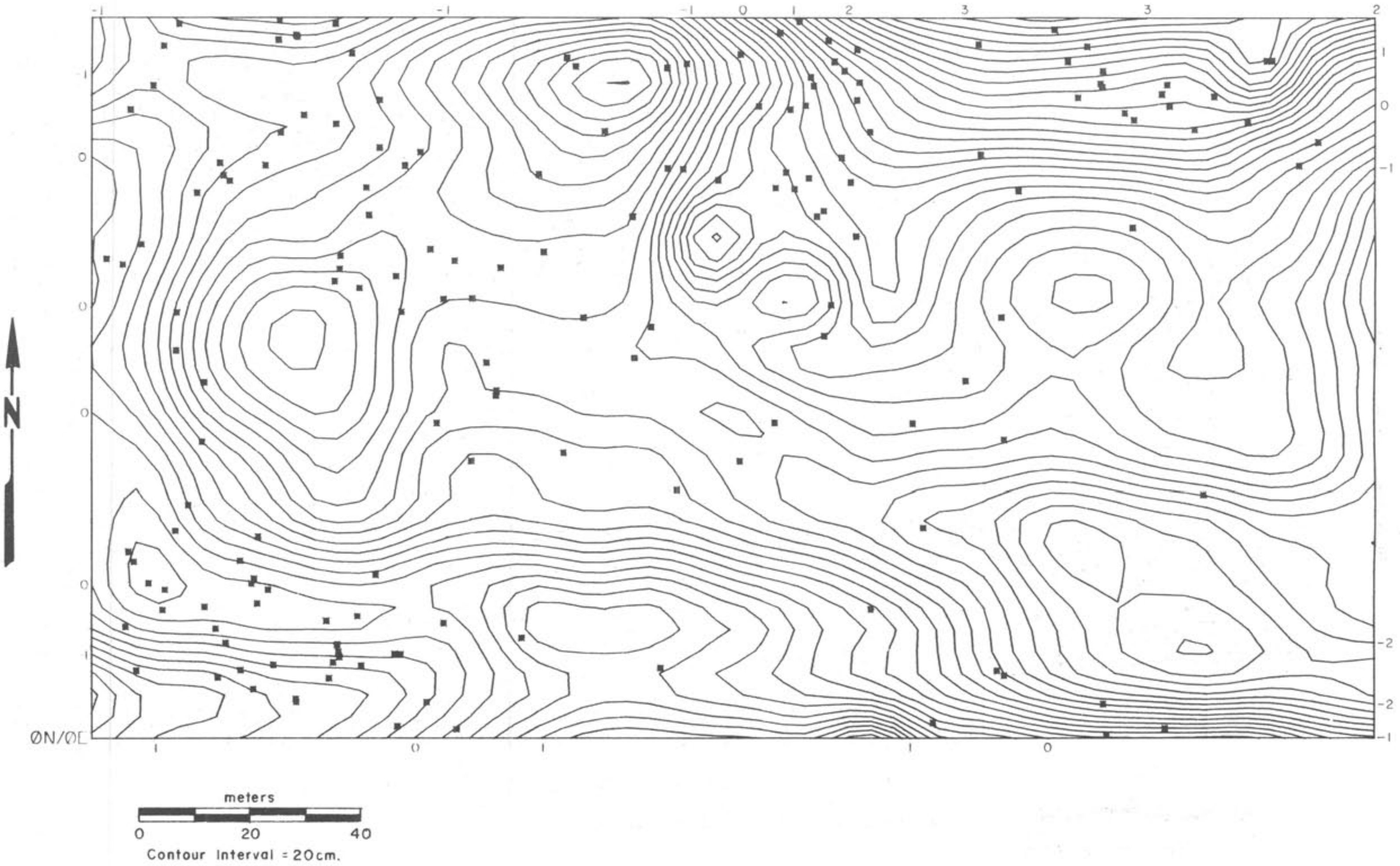

Figure 3.12. CalComp plot of modified lithics occurring in contour grid area.

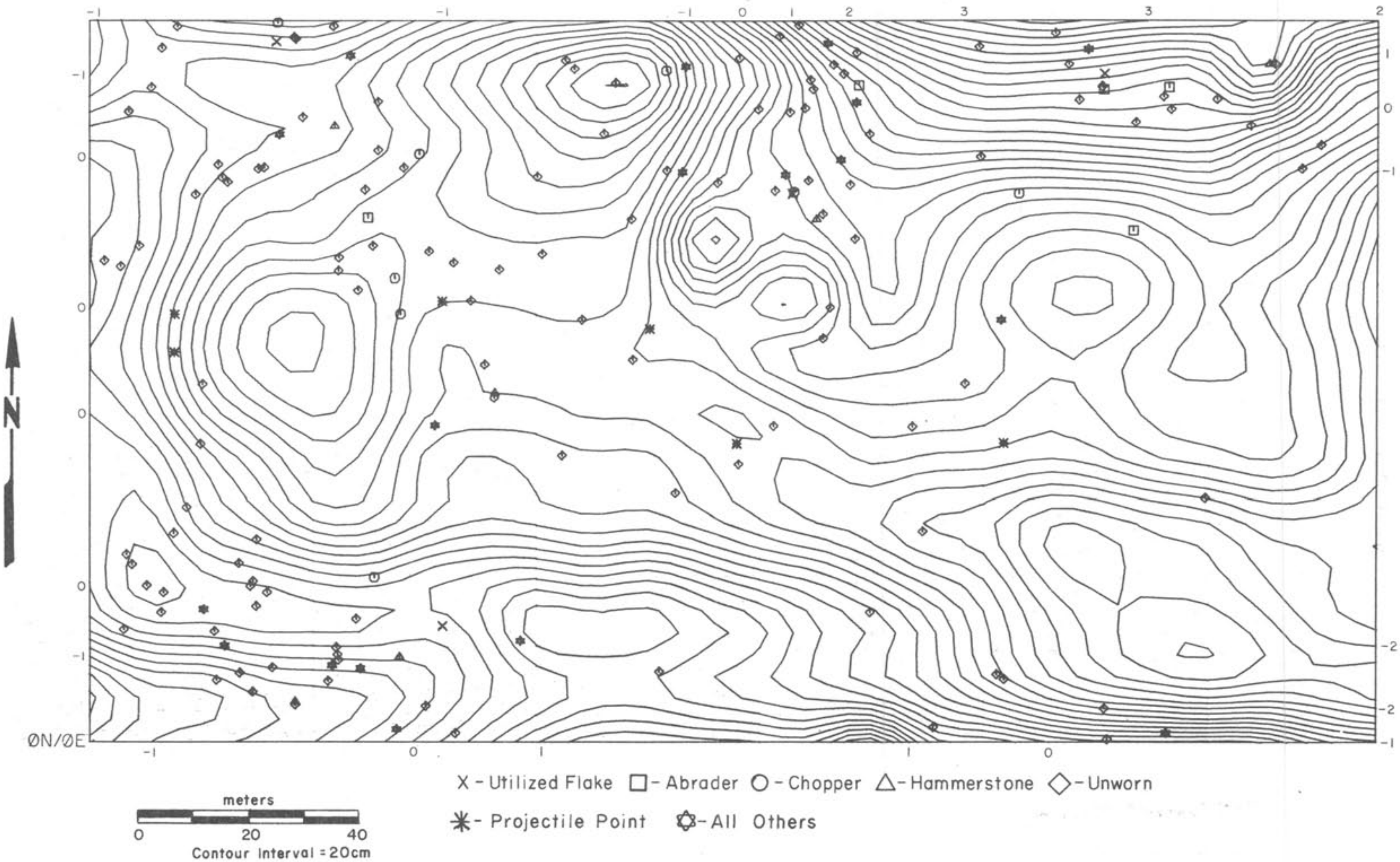

Figure 3.13. CalComp plot of selected prehistoric artifact classes occurring within contour grid area.

creasing attention among other researchers, and several objective, statistical techniques for investigating spatial patterning of occupational debris have been proposed and tested in archeological contexts. While most of these techniques have been borrowed from other disciplines, this does not necessarily detract from their potential utility for archeological data. What is lacking, however, is an explicit programmatic approach to spatial analysis that recognizes unique, complicating aspects of cultural data as well as interpretive limitations of rendering spatial variability into summary descriptive statistics. It is not enough that we now have the means to measure degree of spatial aggregation in our data or its statistical significance. Such measures, while useful, get us very little closer to an objective understanding of form and content of spatially disposed phenomena or cultural and/or natural processes that are reflected in them.

Perhaps the single most reasoned consideration of spatial analysis in an archeological setting is Whallon's (1973, 1974) work with quantitative techniques for detection of pattern on occupation floors. Although his investigations are limited to application of only two such techniques from among a multitude that have been developed over the last 20 years in quantitative plant ecology and human geography, he proposes a specific analytic program of general utility:

> The first step is to determine whether the distribution of artifacts or items of each class being considered is essentially random or shows a significant tendency toward spatial aggregation or concentration on a scale smaller than the entire area under analysis. The second step is to then take those classes of artifacts or items which do show significant trends toward concentration and to reorganize the original data so that similarities or correlations which are based on, or most strongly reflect, these concentrations can be calculated and are organized or displayed in some form, either as an ordered matrix or as a tree defined by cluster analysis, so that groups of artifacts and items which are similarly distributed over the area considered are defined, along with the relationships among these groups or clusters (Whallon 1973:266-267).

A similar analytic system has been used to investigate the distribution of occupational debris at 45-SA-17b; however, there are certain important deviations. The density of debris and the number of functional types is such that computations of similarities or correlations among artifact classes would be statistically meaningless. Therefore, the third step of Whallon's program has not been undertaken. It should be stressed, however, that regardless of the specific limitations of the present data, other researchers are urged to broaden the scope of this final programmatic step. Whallon's suggestion of examining intercorrelations among artifact classes at the spatial scale which shows the most significant trend towards concentration may not be the best means of elucidating spatial structure. This wholly *R*-type analysis, while providing an indication of significant co-associations among the variables or classes under consideration, by itself cannot demonstrate the *spatial* characteristics of those variable or class groupings that are identified. Instead, a *Q*-type analysis also should be performed to identify and plot those sets of spatial units (e.g., grid quadrats) which share similar artifact class contents (see Jermann 1973 for a consideration of Q-type techniques in examining intrasite spatial structure). Unlike *R*-type analysis, *Q*-type analysis of an area should be conducted at a scale lower than that at which the most significant trend towards concentration occurs in order to investigate the structure and contents of such concentrations. Cluster and factor analysis techniques are applicable to *Q*-type as well as *R*-type investigations. Whatever the particular multivariate statistical techniques employed, the most important step in *Q*-type analysis is spatially plotting the members of any clusters/groups that are identified. By this means the researcher can determine whether the members of a given cluster, which have been statistically isolated solely on the basis of their artifactual contents, also display spatial contiguity. Those which do may well represent activity areas.

Whether *R*-type or *Q*-type approaches are used, we must first determine the scale, if any, at which significant departures from random occur in the distribution of artifacts. Analytic methods useful for these determinations can be divided into two general categories based on degree of referential control required. The most demanding, nearest-neighbor analysis, requires exact two-dimensional coordinates for all objects under investigation. The present analysis made use of a technique originally proposed by Clark and Evans (1954) and recently applied by Whallon (1974) to an archeological situation -- mean estimation nearest-neighbor analysis. The second analytic group, here termed quadrat analysis, following Rogers (1974), makes use of data in the form of counts for a planar study area divided into a grid with equal-sized cells, called quadrats. Such quadrats are usually square-shaped, and analysis seeks to obtain indications of the random or nonrandom character of the process that generated the distribution under study. Obviously, the less demanding spatial provenience requirements of quadrat analysis methods have considerably greater applicability since exact artifact locations rarely are uniformly recorded in usual archeological contexts. One such quadrat analysis technique is illustrated here: calculation of Morisita's Index of Aggregation, I_d. A second technique, dimensional analysis of variance (Whallon 1973), also was applied to the data, but failed to indicate significant patterning at any scale because of low artifact density. Both techniques require a block of contiguous quadrats with dimensions of either $2^n \times 2^n$ or $2^n \times 2^{n+1}$. While this can be a severe restriction, it often can be met by considering a smaller area, either by dividing the study area into sub-areas and examining each separately or by adding enough imaginary or "dummy" quadrats to create required dimensional relationships. For purposes of this analysis, a combination of these options was used. The 130 x 230 m study area within which previous plots have been depicted was modified such that final analytic dimensions were 128 x 256 m; this necessitated adding 26 m of dummy grid units to the eastern end of the survey block.

Mean Estimation Nearest-neighbor Technique

The use of nearest-neighbor analysis in the study of spatial pattern is based on a comparison of observed first nearest-neighbor distances to the expected distribution under a random point process. Calculation of expected mean distance to the first nearest-neighbor, although derived from a somewhat complex statistical argument (see Whallon 1974:19-21), is quite straightforward and can be expressed by the formula:

$$\bar{r}_e = 1/(2\sqrt{p}),$$

where $\bar{r}_e$ is the expected mean distance and p is the density of objects in the area under consideration.

A nearest-neighbor index can then be calculated simply by taking the ratio of the observed mean nearest-neighbor distance, $\bar{r}_o$, to the expected mean distance:

$$R = \bar{r}_o/\bar{r}_e,$$

where R is the nearest-neighbor index.

Clark and Evans (1954) have shown that a perfectly regular point pattern leads to an R = 2.1491, a random point pattern to an R = 1, and, expectedly, a perfectly clustered point pattern to an R = 0. A level of significance also can be calculated for a given value of R. This calculation assumes, however, a random distribution of nearest-neighbor distances. The method proceeds as follows. First, the standard error of $\bar{r}_e$ is calculated as

$$\sigma\bar{r}_e = 0.26136/\ N_p,$$

where N_p is the total number of objects in the study area. From this, a two-tailed level of significance can be determined by

$$z_\alpha = (\bar{r}_o - \bar{r}_e)/\sigma\bar{r}_e.$$

z_α, a standard normal deviate, can then be compared to a table of areas under a normal curve. The 5% level of significance is given by a z_0 value equal to 1.96.

Nearest-neighbor statistics were calculated for each of four general assemblage constituents. The results of these analyses are presented in Table 3.2. In all cases except that of "slabs," the value of the nearest-neighbor index, R, is both significantly non-random and rending towards "clustered." However, none of these "significantly clustered" indices is very close to a value of 0. This can probably be attributed to the extremely low object densities even though there are adequate sample sizes.

Besides problems of density dependence, nearest-neighbor analysis suffers from several other difficulties. Because the technique makes use of measured distances between a set of points and their nearest-neighbors, difficulties are encountered along study area boundaries. Also, sole reliance on first nearest-neighbor distance may lead to erroneous conclusions in situations where the point pattern consists of a configuration of "clumps" (Rogers 1974:10). As a means of dealing with this problem, Thompson (1956) and others suggest the use of subareas or nth nearest-neighbors. The latter would involve calculating average distances to the first, second, third, ..., nth nearest-neighbors and comparing each to the random model.

Perhaps the most serious limitation of the method is the difficulty of generating probability distributions of nearest-neighbor distances for spatial point processes other than random. Although non-random patterns can be ranked according to degree of regularity or clustering, it is exceedingly difficult to infer the probability models that generated them (Rogers 1974:11). This is not a problem with quadrat techniques and for this reason attention will now be turned in that direction.

MORISITA'S INDEX OF AGGREGATION, I_d

Morisita's I_d is a means of characterizing spatial dispersion for quadrat data by calculating diversity from quadrat to quadrat in object density. Calculation of the index is given by the formula:

$$I_d = (T/j) \sum_{i=1}^{T/j} \frac{n_i(n_i - 1)}{N(N - 1)},$$

where
T = total number of quadrats,
j = number of quadrats per block,
n_i = number of objects in the ith block,
N = total number of objects,
(Morisita 1959).

The index is calculated for a series of block size levels in which at any given level the block size is twice that of the preceding block size. Because one is dealing with counts in a grid of square quadrats, block shape alternates between being a square or rectangle as one proceeds through the sequence of

Table 3.2. Mean Estimation Nearest-Neighbor Analysis of General Artifact Classes.

CLASS	NUMBER	R_e	R_o	R	Z_a
FIRE-CRACKED ROCK	419	4.224	3.116	0.738	10.253
PEBBLES/ COBBLES	579	3.593	2.854	0.794	9.462
SLABS	47	12.611	12.219	0.969	0.404
MODIFIED LITHICS	168	6.670	5.547	0.832	4.164

Table 3.3. Summary of Morisita's Analysis of Aggregation for Fire-cracked Rock.

BLOCK SIZE	MORISITA'S INDEX, I_d	I_d/I_{2d}	F	DEGREES OF FREEDOM
1	11.380	0.992	1.555	8191
2	11.974	1.193	2.120	4095
4	10.033	1.371	2.845	2047
8	7.320	1.177	3.582	1023
16	6.221	1.075	5.271	511
32	5.785	1.438	8.844	255
64	4.024	1.456	10.953	127
128	2.763	1.210	12.699	63
256	2.284	1.268	18.311	31
512	1.801	1.212	23.315	15
1024	1.486	1.140	29.992	7
2048	1.304	1.037	43.401	3
4096	1.257	-----	108.623	1

successive block size levels (Whallon 1973:270). Thus, at alternate levels of block size, one is faced with choosing the orientation of rectangular blocks. While it is recommended that the index be calculated on the basis of both orientations (since significantly different results may arise, depending upon the shape, size, and orientation of any spatial clusters), only one, an east-west orientation, is considered here.

Morisita's Index has several advantages for quadrat data. Hairstone et al. (1971:339) observe that the index does not necessitate assumptions about the particular form of the probability generating function for a given frequency distribution. Morisita has shown that I_d changes in systematic ways with block size; the nature of this change is dependent upon the pattern of a distribution and size of any clusters.

Theoretical values of I_d vary from a minimum of 0 (perfectly uniform) to a maximum of T/j (perfectly clustered). The index is equal to 1 for a random (Poisson) distribution. Importantly, Stiteler and Patil (1971) have shown that the expected value of I_d (=1) is independent of block size.

As a means of testing the statistical significance of I_d's departure from random, Morisita originally proposed that the calculated value

$$F = \frac{(I_d(N - 1) + T/j - N)}{(T/j - 1)}$$

be compared with the value of chi-square, χ^2, with T/j -1 degrees of freedom. However, Stiteler and Patil also have shown that F is actually a variance-to-mean ratio and thus for patterns approximating a Poisson distribution, will be equivalent to s^2/σ^2 and will have a distribution of χ^2/df. While it is possible to calculate upper and lower significance levels for any desired confidence interval, we have chosen to compare F with χ^2 (.025 and .975)/(T/j - 1), i.e., a 95% confidence interval.

I_d and F were calculated for the distributions of fire-cracked rock, pebbles/cobbles, and modified lithics. Minimum block size for this analysis was a 2x2 m quadrat. Results of these investigations are presented in Tables 3.3 to 3.5. As is apparent, the value of I_d is greater than unity, indicating clustering, for each of the three distributions at effectively all block sizes.

Figures 3.14 to 3.16 graphically display the relationship between I_d and F and the 95% confidence interval. Not only is there a marked tendency towards clustering for all three material types, but F values are consistently significant at the 95% confidence level.

Table 3.4. Summary of Morisita's Analysis of Aggregation for Pebbles/Cobbles.

BLOCK SIZE	MORISITA'S INDEX, I_d	I_d/I_{2d}	F	DEGREES OF FREEDOM
1	8.665	1.110	1.541	8191
2	7.809	1.114	1.961	4095
4	7.013	1.342	2.698	2047
8	5.226	1.090	3.388	1023
16	4.795	1.289	5.222	511
32	3.719	1.315	7.164	255
64	2.828	1.298	9.320	127
128	2.179	1.037	11.817	63
256	2.101	1.270	21.531	31
512	1.654	1.264	26.183	15
1024	1.309	1.062	26.552	7
2048	1.232	1.065	45.745	3
4096	1.157	-----	91.850	1

Table 3.5. Summary of Morisita's Analysis of Aggregation for Modified Lithics.

BLOCK SIZE	MORISITA'S INDEX, I_d	I_d/I_{2d}	F	DEGREES OF FREEDOM
1	6.424	1.833	1.111	8191
2	3.504	1.200	1.102	4095
4	2.920	1.250	1.157	2047
8	2.336	0.985	1.218	1023
16	2.372	1.066	1.449	511
32	2.226	1.129	1.803	255
64	1.971	1.099	2.277	127
128	1.793	1.069	3.102	63
256	1.677	1.038	4.645	31
512	1.615	1.202	7.848	15
1024	1.344	1.187	9.197	7
2048	1.132	1.061	8.365	3
4096	1.067	-----	12.167	1

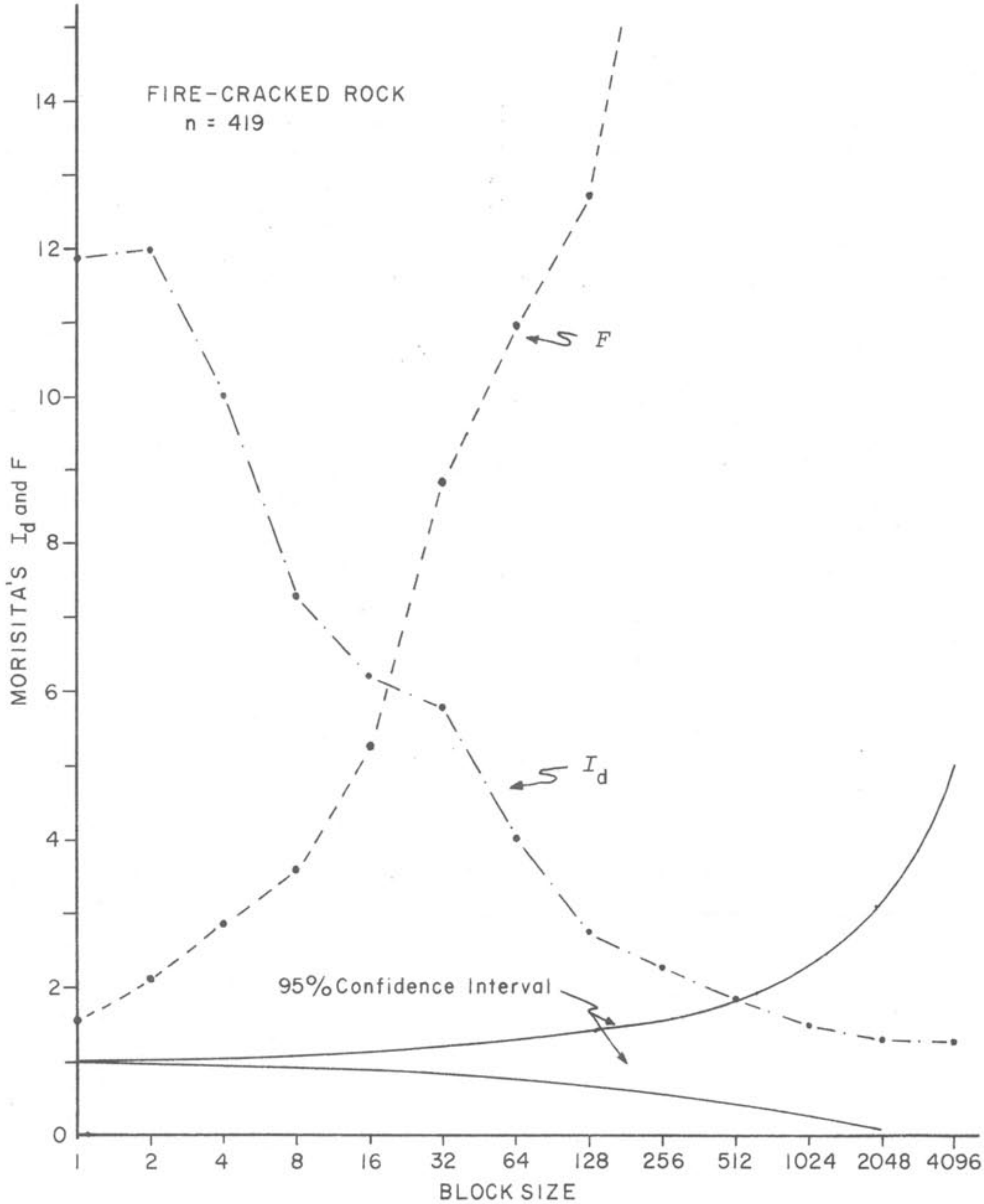

Fig. 14. Graphs of Morisita's I_d and F statistics versus block size for fire-cracked rock.

Figure 3.14. Graphs of Morisita's $\underline{I_d}$ and $\underline{F}$ statistics versus block size for fire-cracked rock.

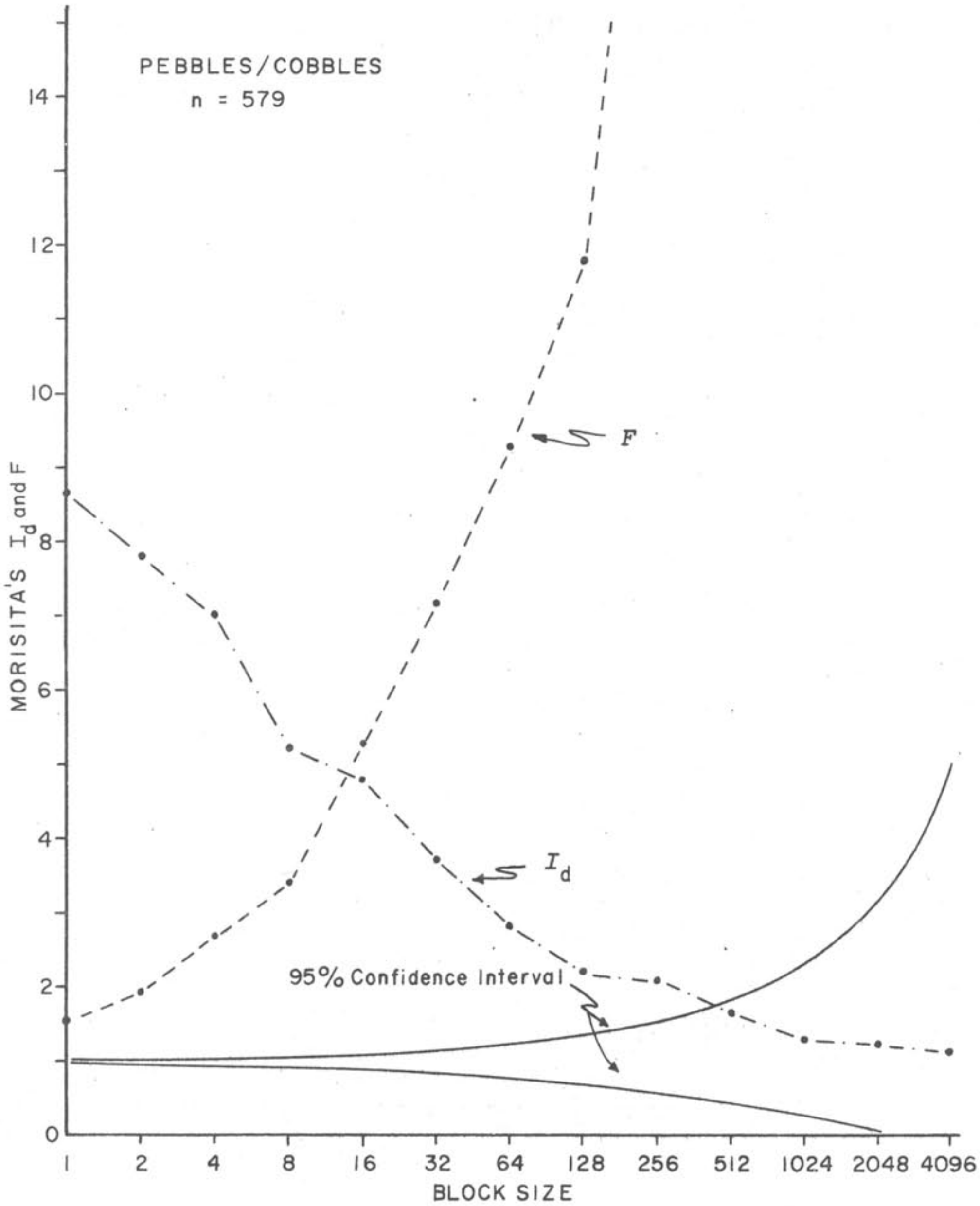

Figure 3.15. Graphs of Morisita's $\underline{I}_d$ and $\underline{F}$ statistics versus block size for pebbles/cobbles.

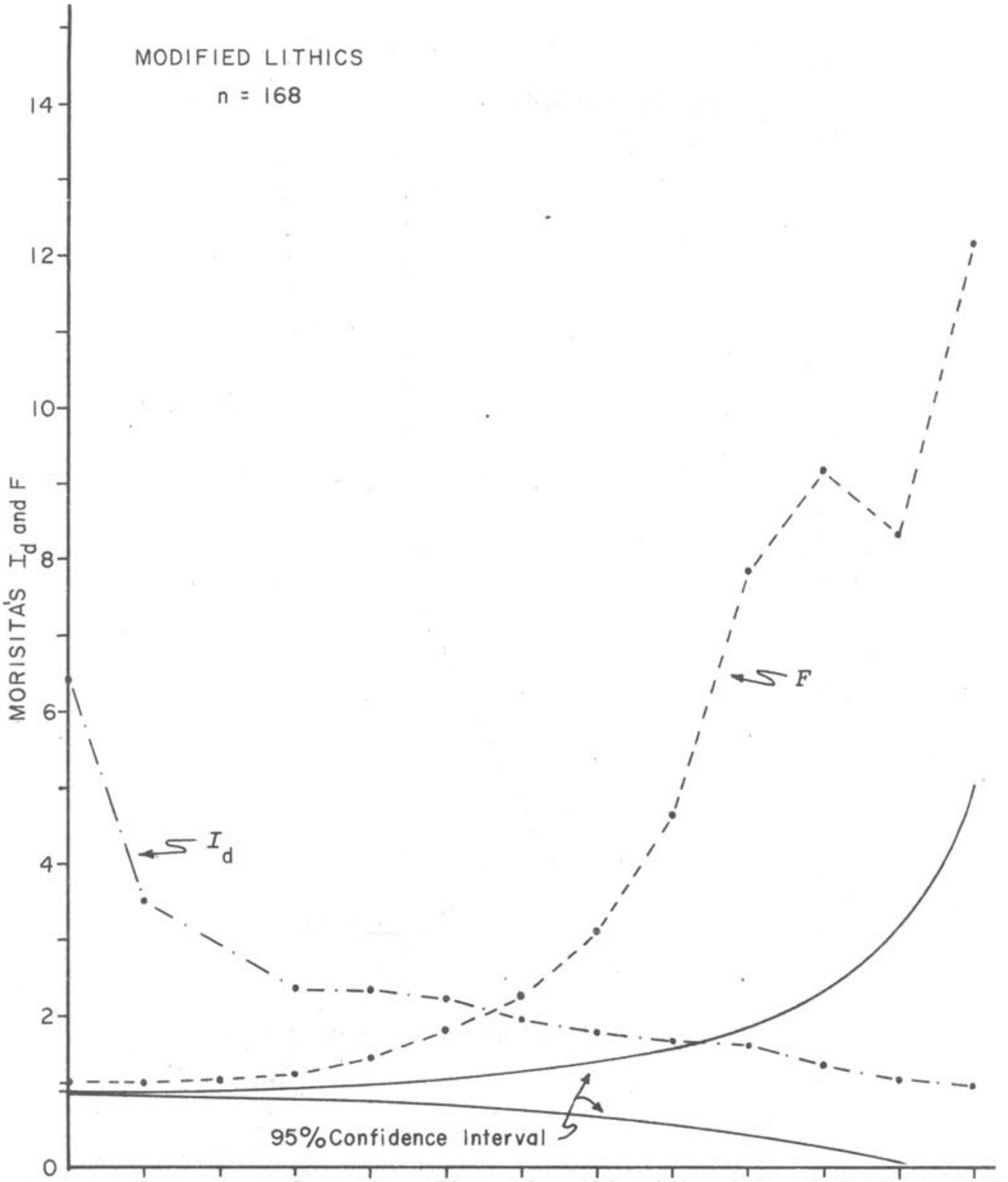

Figure 3.16. Graphs of Morisita's $\underline{I}_d$ and $\underline{F}$ statistics versus block size for modified lithics.

Given a series of I_d values uniformly indicating a tendency towards clustering, we are faced with a situation of being unable to discern the scale(s) at which clustering occurs. Morisita (1959) has suggested plotting the ratio I_d/I_{2d} against block size (taken as 2j). The resultant graph yields peaks at block sizes corresponding to the scales of pattern present in a given distribution. Figure 3.17 presents such a plot for each of the three distributions. Interestingly, peaks indicative of patterning occur approximately at block sizes 8, 64, and 512 in all three cases. This indicates that the spatial dispersions of all three distributions are not only similar but also largely coincident, a conclusion reached previously on the basis of a subjective interpretation of mapped distributions.

The Structure of Spatial Pattern

In the preceding paragraphs two techniques were applied to the data to determine whether material components of the site assemblage displayed any spatial patterning. In all cases other than distribution of basaltic slabs, significant departures from a random dispersion were found, and distributions tended towards clustering. While this may be an important observation, summary descriptive measures are of little utility in investigating specific locational aspects of site patterning; however, such investigations are necessary to any understanding of spatial structure of past cultural activities.

Analyses based on Morisita's Index of Aggregation indicated that patterning occurs at three different block sizes: groups of 8, 64, and 512 two-meter grid units. For purposes of the present analysis, the structure of spatial patterning at block size 64 (16 x 16-meter grid units) was selected for further investigation. Given an interest in examining intrasite structure at this particular scale, quadrats were grouped at a scale lower than that at which pattern was indicated. In this case an eight-meter grid was used.

Given the low density of material remains and the small number of data classes having any more than a few members, consideration is restricted to distributions of fire-cracked rock, pebbles/cobbles, and modified lithics. The first step in the analytic process was to map the contents of the eight-meter grid using the SYMAP plotting program. This program produces shaded contour maps in which the density of the variable/class under investigation is structured according to a set of user-defined contour intervals. Although several techniques can be used to select contour intervals, standard scores were chosen for all maps other than that displaying the distribution of modified lithics (see Jermann and Dunnell 1979

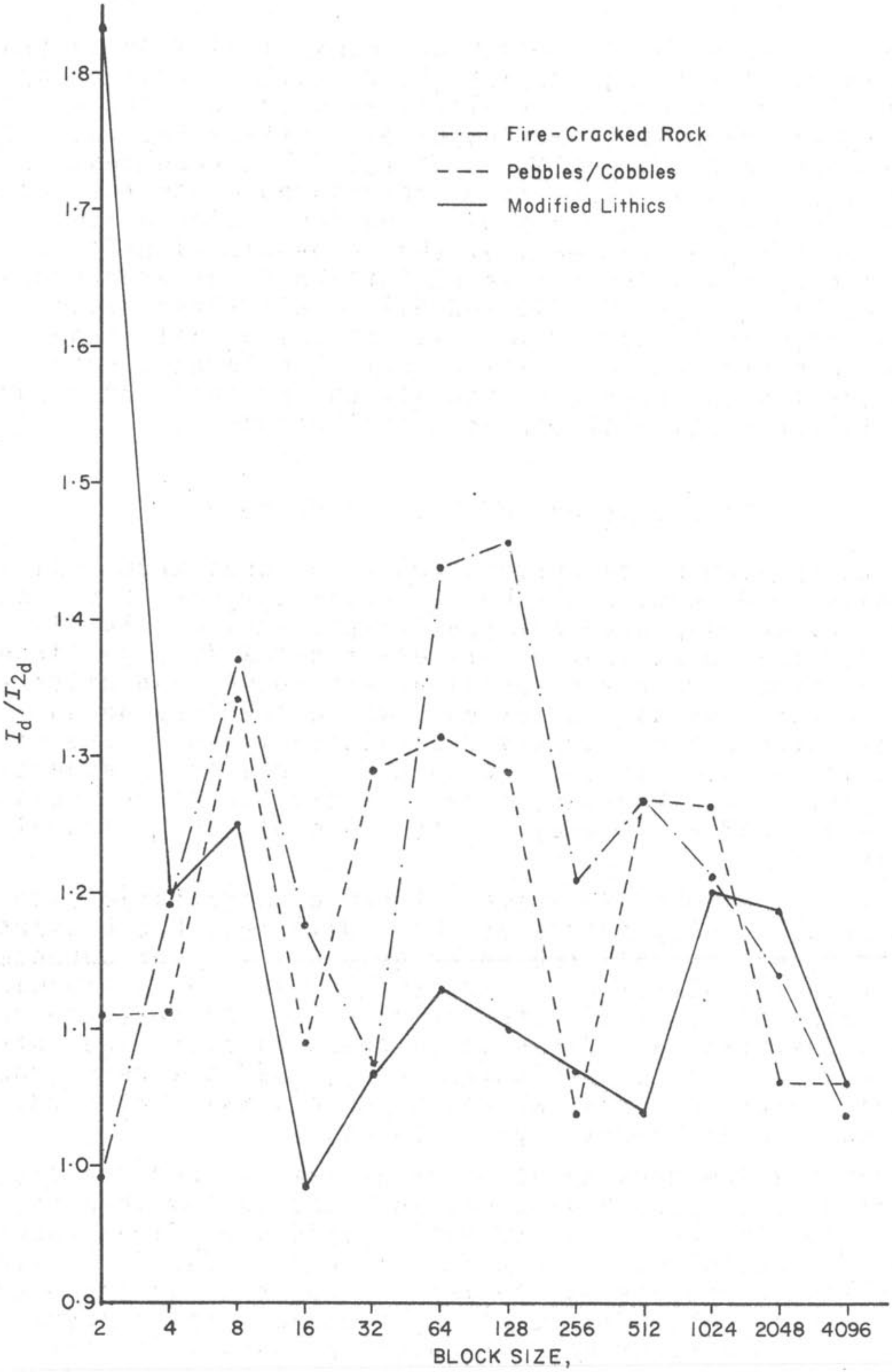

Figure 3.17. Graphs of $\underline{I}_d / \underline{I}_{2d}$ versus block size for selected material categories.

for an in-depth treatment of interval selection techniques). The technique of standard scores makes use of the mean and standard deviation of a variable's distribution to re-scale or standardize the data. For a given quadrat, the standard score is calculated as follows:

$$z = (x - \overline{x})/s.d.$$

where z is the standard score for a given variable/class, x is the frequency of occurrence in the quadrat of interest, $\overline{x}$ is the arithmetic mean of the variable/class of interest, and s.d. is its standard deviation.

Following calculation of standard scores for classes of interest, the data were used by SYMAP to produce contoured (isopleth) distributional maps. Two such maps are illustrated in Figs. 3.18 and 3.19. Additionally, the spatial dispersion of modified lithics was mapped (Fig. 3.20); however, contour intervals based on unstandardized frequencies were used because the low density of this class precluded use of standard scores. Table 3.6 summarizes contour intervals for all mapped distributions in terms of unstandardized frequencies. In both instances where standard score-based intervals were used, the first contour level includes negative (i.e., "impossible") values. Such non-existent intervals will occur when a variable's frequency distribution is negatively skewed about the mean, and the mean lies sufficiently close to zero. This characteristic of the standard score interval selection technique in no way detracts from its general utility, however. By transforming raw frequency data into a standardized format, the mapped distributions of two or more variables/classes can be compared even though each may have quite disparate value ranges.

An examination of the distribution of fire-cracked rock (Fig. 3.18) reveals a tendency for this class of materials to occur as relatively extensive patches over the project area's surface. This pattern is unlike that noted in previous investigations at 45-SA-17 (Dunnell and Lewarch 1974b:Fig. 6) in which much smaller, but denser, isolated clusters occurred. Such differences may well reflect variation in the kinds and intensity of cultural activities at the two locales. One also has to be aware of the fact, however, that if attention is confined strictly to those areas displaying maximal occurrences of FCR (i.e., those units lying within contour interval 5), interpretations will be based on the presence of only three or more objects/unit (see Table 3.6). With this in mind, it would be premature to conclude that patches of FCR represent fire hearths or the like. It is more likely that they may be the remains of features that were scattered by the site's inhabitants and subsequently further dispersed by historic plowing.

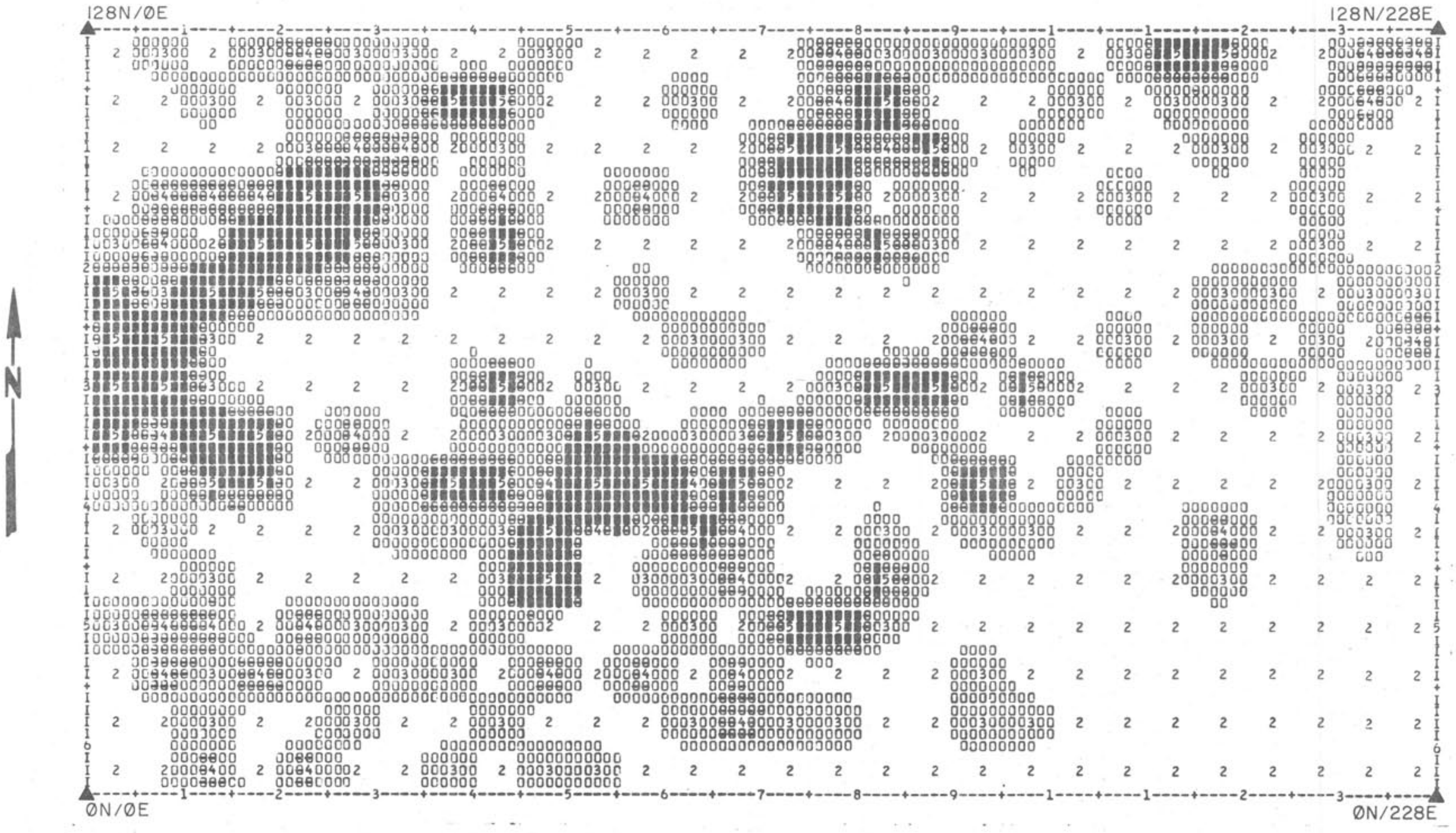

Figure 3.18. SYMAP of fire-cracked rock numbers using standard scores interval selection method (see Table 3.6. for frequency equivalents of intervals).

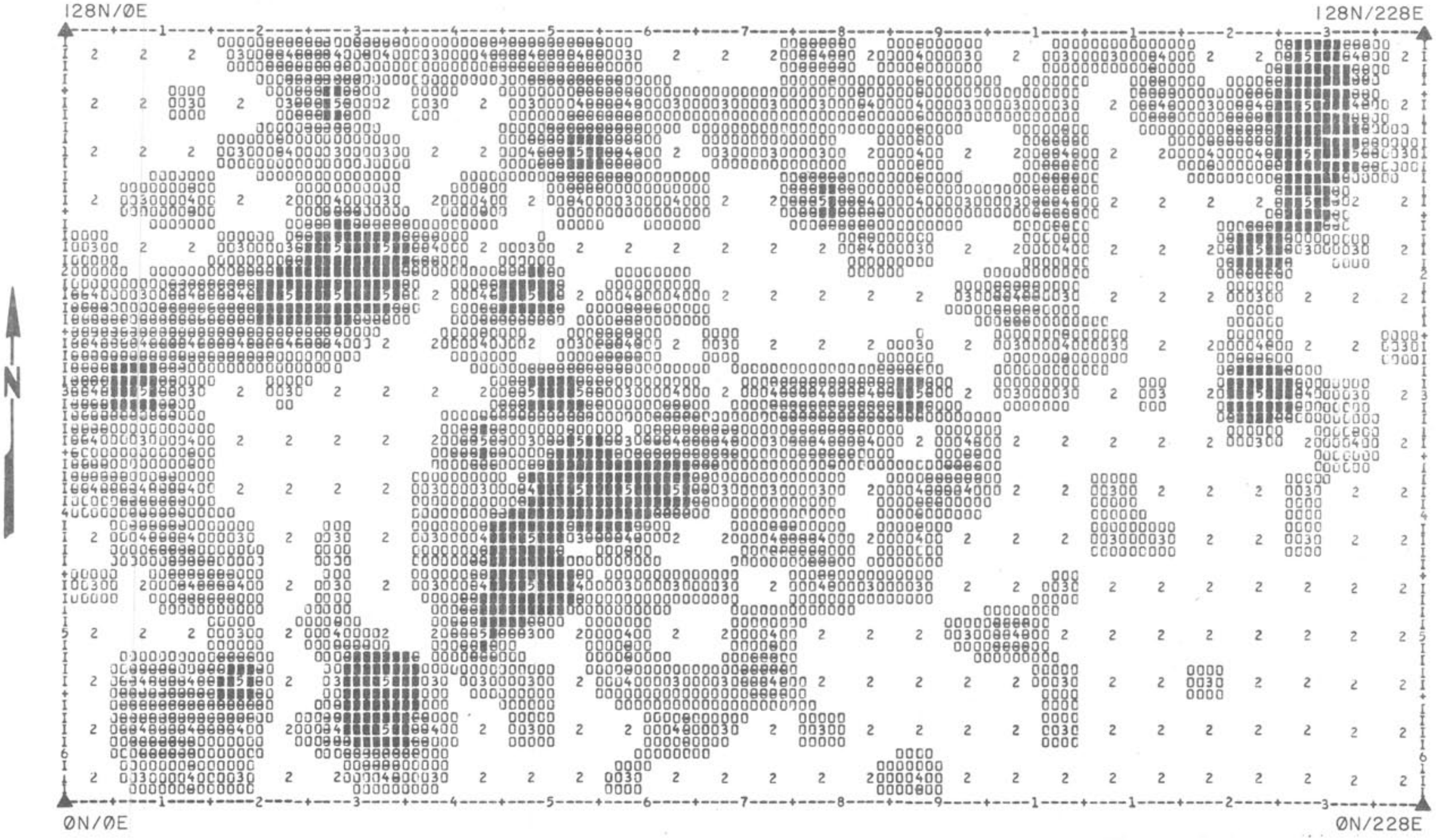

Figure 3.19. SYMAP of pebble/cobble number using standard scores interval selection method (see Table 3.6. for frequency equivalents of intervals).

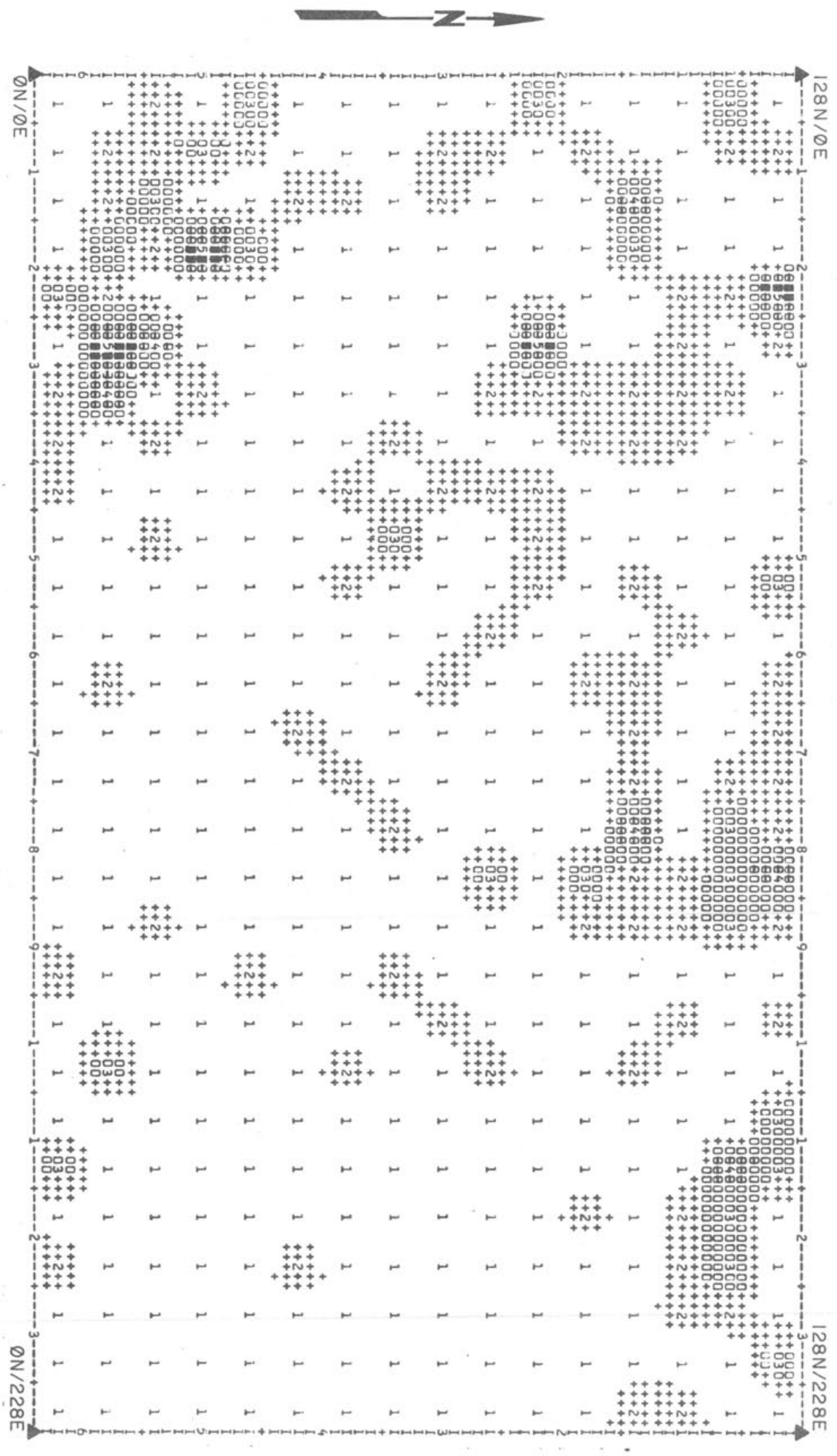

Figure 3.20. SYMAP of number of modified lithics (see Table 3.6. for frequency equivalents of intervals).

Table 3.6. Contour Intervals Used For SYMAPs of Assemblage Constituents Based on Frequency/Eight-Meter Quadrat.

CONTOUR INTERVAL*	FIRE-CRACKED ROCK**	PEBBLES/ COBBLES***	MODIFIED LITHICS****
1	-0.9	-0.9	0
2	0	0.6	1
3	1.5	2.0	2
4	2.8	3.5	3
5	>2.8	>3.5	>3

* Values associated with intervals are upper limits.

** $\bar{x} = 0.94$; sd = 2.18

*** $\bar{x} = 1.29$; sd = 2.59

**** $\bar{x} = 0.38$; sd = 0.72

The distribution of unmodified pebbles/cobbles (Fig. 3.19) displays a similar pattern to that noted for FCR, although patches tend to be spatially more extensive. Again, the visual impression gained from the distribution of this category of materials is that it somehow is tied to the distribution of FCR. As mentioned previously, the simplest explanation is that the occurrence of pebbles/cobbles represents the same cultural activities reflected by FCR.

Finally, the distribution of modified lithics (Fig. 3.20) once again underscores the relatively low density of this assemblage constituent. It is worthwhile to observe, however, that several small clusters of these remains do occur and that they lie in the vicinity of the broader patches noted for fire-cracked rock and pebbles/cobbles. Importantly, the two types of clusters (i.e., small, low-density concentrations of lithics and relatively broad scatters of FCR and pebbles/cobbles) are not spatially coincident. This suggests that the site's prehistoric occupational debris may represent short-term (hence the low density of material remains) use of the area by a few individuals for a limited range of activities. Although the data are such that this conclusion must be largely a matter of conjecture, the existing evidence is not counter to such an explanation. To go perhaps one step further, it might also be suggested that this site represents a temporary summer camp or way-station occupied by a single band of people. Insofar as the kinds of activities that may have been carried out at this locality are concerned, the data at hand offer little enlightenment. While the presence of fire-cracked rock is certainly indicative of heating-related activities, lack of any associated floral or faunal remains as well as the small number of tool objects makes further functional determinations difficult. Indeed, it may well be that scattered concentrations of FCR and unmodified pebbles/cobbles are nothing more than remnants of camp fires used to heat the site's occupants or to cook game. Even less can be inferred from the light scatter of tools and chipping detritus. Their low density and lack of spatial association lead to the conclusion that little if any primary manufacturing activity took place here and that their presence can best be explained as a consequence of limited secondary manufacturing activities (e.g., tool resharpening) and casual loss and/or purposeful abandonment. The latter suggestion is particularly appropriate for heavy core implements occurring in the assemblage. The overwhelming majority of these objects displays a high degree of crushing/chipping wear on their working edges. Because of their relatively bulky nature and ease of manufacture, it is reasonable to conclude that they were made, used, and discarded in the same general vicinity. Their specific function, however, remains enigmatic. Perhaps they represent tools used in the processing of wood. Whatever their use(s), these objects are the most recurrent tools in the cultural assemblage and as such their use must have been one of the principal reasons for site occupation.

SUMMARY AND CONCLUSIONS

Analysis of 45-SA-17b's cultural assemblage has revealed several interesting spatial relationships. Fire-cracked rock and unmodified pebbles/cobbles, by far the most abundant material components, tend to occur as large, spatially coherent patches at several non-overlapping areas on the surface of the site. Based on internal distributional analyses and evidence obtained from subsurface testing, it appears that these low density clusters represent scattered remains of much denser, more coherent features such as fire hearths or earth ovens. Although quite limited in numerical frequency, flaking detritus and tool objects tend to be spatially associated but not coincident with the aforementioned clusters. This, taken with the lack of any perceptible spatial co-association in distributions of individual functional types, leads to the conclusion that aboriginal use of this area was limited to a single occupational episode that included a very restricted range of cultural activities. The most plausible explanation of such a pattern is that the site represents a temporary summer camp occupied by two or more family groups. The preponderance of heavy, well-used core tools further suggests the major focal point of cultural activities may have been wood-working.

A stylistic analysis of the limited projectile point sample, based on a typological system that has been shown to be useful for relative chronological determinations in both the Portland Basin and Columbia River Gorge area, indicates the site may date to what Pettigrew (1977) has termed the Merrybell phase (600 B.C. - A.D. 200). This would make 45-SA-17b significantly earlier than sites occurring in the Bonneville Dam vicinity immediately downstream (Dunnell and Campbell 1977). At the same time, this chronological placement would be in considerable disagreement with the Cascade phase (ca. 4,500 - 6,500 B.C.) association attributed to 45-SA-17 (Dunnell and Lewarch 1974b). While the latter conclusion is based on the occurrence of only a single projectile point, the temporal assignments for both assemblages still could be correct. Although the two "halves" of the site are located only a short distance from one another, 45-SA-17 occurs on first terrace deposits while 45-SA-17b occurs on second terrace deposits. Even more importantly, the two artifact assemblages are distinct both functionally and spatially. This would argue for some degree of temporal disjunction. In the absence of contrary evidence, it can be concluded that the two site loci represent distinct occupational episodes.

Quite apart from whatever value 45-SA-17b may have for interpreting prehistoric cultural patterns in the lower Columbia River region, the site offers an excellent opportunity to test a wide variety of intrasite pattern description and analysis techniques. Because recovery tactics resulted in an assemblage with known, absolute three-dimensional locations for all objects, both nearest-neighbor and quadrat analysis techniques could be applied to the data. While the density and functional variability of artifact occurrences at the site precluded meaningful statistical analysis of intrasite similarities or correlations in spatial dispersions, pattern description measures noted significant departures from randomness for virtually all assemblage constituents. Reorganization of the data into a grid smaller than the scale at which patterning was indicated permitted mapped representations of artifact distributions necessary for investigating internal site structure. The logical extension of these studies is characterization of 'activity areas' within a site. Although present data did not warrant this treatment, workers in other circumstances should apply both R-type and Q-type techniques to their spatially disposed phenomena in an attempt to isolate such structures. Classification and description of the numbers, sizes, contents, and spatial arrangements of activity areas within a site can provide analytic building blocks necessary for subsequent inter-and intrasite functional interpretations.

Systematic surface collection can result in data ideal for spatial investigations. To be of maximum value for analyses within a spatial perspective, recovery techniques should provide for collection over the largest practical continuous area. Of even greater importance is the scale at which provenience information is gathered, because it will establish a minimum limit below which spatial patterning cannot be identified. Obviously, the most informative recovery strategy would be one resulting in precise three-dimensional locational information for all data of interest. Such a strategy has been put into practice both here and elsewhere (e.g., Gunn and Mahula 1977). To be of practical value, data recovery and recording techniques must be both simple and accurate; there is little benefit in attempting to collect precise locational information if it is at the expense of achieving adequate areal coverage. The technique developed for use at 45-SA-17b offers an efficient means of generating accurate referential data and should be useful in a variety of circumstances.

Finally, current investigations have underscored the effects of surface conditions on data recovery as well as the potential value of "preparing" a uniform surface plane prior to collection. Although mechanical alteration of site surfaces is not recommended universally, especially in situations where evidence of past agricultural disturbance is lacking, purposeful plowing/disking can be efficacious in reducing recovery biases that arise as a consequence of differential surface exposure.

The data also suggest that any single collection from the surface of a site may not be statistically representative of the total population. In the current case, this was particularly true of the sample collected prior to any surface modification. It is difficult, however, to test differences among successive collections because in sampling without replacement the character of the parent population may vary in a non-uniform manner. Given a finite artifact pool from which samples can be drawn, variability among repeated collections is likely to be most pronounced in the size distribution of objects comprising each sample. The probability that any given object is collected in a given sample is not only a function of the relationship between the number of items in the population and in the sample but also is dependent upon the absolute size of the object. Large artifacts will have a better chance of being collected because of their greater size in relation to the total volume of artifacts in a population and because of the greater likelihood they will be exposed following surface modification (e.g., plowing). One immediate consequence of such a relationship is that the average size of objects in a sample should decrease with each succeeding collection of a site surface. This is borne out by results achieved at 45-SA-17b, and indicates that caution should be exercised before presuming a given surface collection is, in fact, representative of the target population.

Ultimately, sample reliability will depend upon the degree to which a variable of interest is normally distributed and the extent of variability within that distribution. In situations similar to that at 45-SA-17b where a variable has a Poisson-like frequency distribution and high variance, potential for systematic collection bias is high, and a single surface collection may not yield a representative sample. While repeated sampling will be needed in such cases, the important point to be made here is that statistically reliable samples <u>can</u> be gained from surface collections and the resultant data <u>can</u> and should be treated with the same analytic and synthetic enthusiasm accorded subsurface assemblages. In view of the tactical and economic benefits to be realized from surface-derived data on a per unit area basis, use of this recovery strategy should assume increased consideration in research designs directed towards community or settlement pattern studies.

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INTERSITE VARIATION IN A BOTTOMLAND LOCALITY: A CASE STUDY IN THE SOUTHERN PRAIRIE PENINSULA

by
Robert E. Warren and Tom Miskell

INTRODUCTION

Human adaptations to the midcontinental Prairie Peninsula have long intrigued students of cultural dynamics. Displaying characteristics of both the Great Plains and the Eastern Woodlands, the Prairie Peninsula is a vast mosaic of grasslands and streamside deciduous forests that stretches eastward from Iowa and northern Missouri to the upper reaches of the Wabash River in Indiana. Because of the area's long term sensitivity to fluctuations of dry Pacific airmasses, anthropologists are interested in the diachronic affects of environmental change on patterns and processes of human behavior. Because of striking contrasts between the area's floral and faunal communities, varying forms of human interaction with the environment are of equal interest, as viewed from the perspectives of both space and time.

The Cannon Reservoir Human Ecology Project, an interdisciplinary research group from the University of Nebraska, is pursuing both these interests on the southern fringes of the Prairie Peninsula (O'Brien and Warren 1980). Its sampling region is a 1,143 km^2 area centered on the middle Salt River valley in northeast Missouri (Fig. 4.1). Composed of intersecting patches of level upland prairie and timbered valley slopes, the region contains segments of a major ecotone and extensive components of two distinct phytocoenoses (Warren 1976).

Of general concern here is the degree of variability within and among these biomes, and the effects this variability had on patterns of prehistoric behavior. Specifically, we focus on variation among surface artifact samples in a small bottomland locality in order to test one aspect of a settlement model developed for the region by O'Brien and Warren (1979). After synthesizing salient aspects of the model and deriving a testable proposition, we outline methods and materials used in the study. We then describe intersite relationships defined on the basis of artifact patterning, associated trends among artifact classes, and covarying nontechnological factors which reflect parameters of site context and site magnitude. Observed variation is accounted for in an empirical hypothesis which is then tested and compared with expected results.

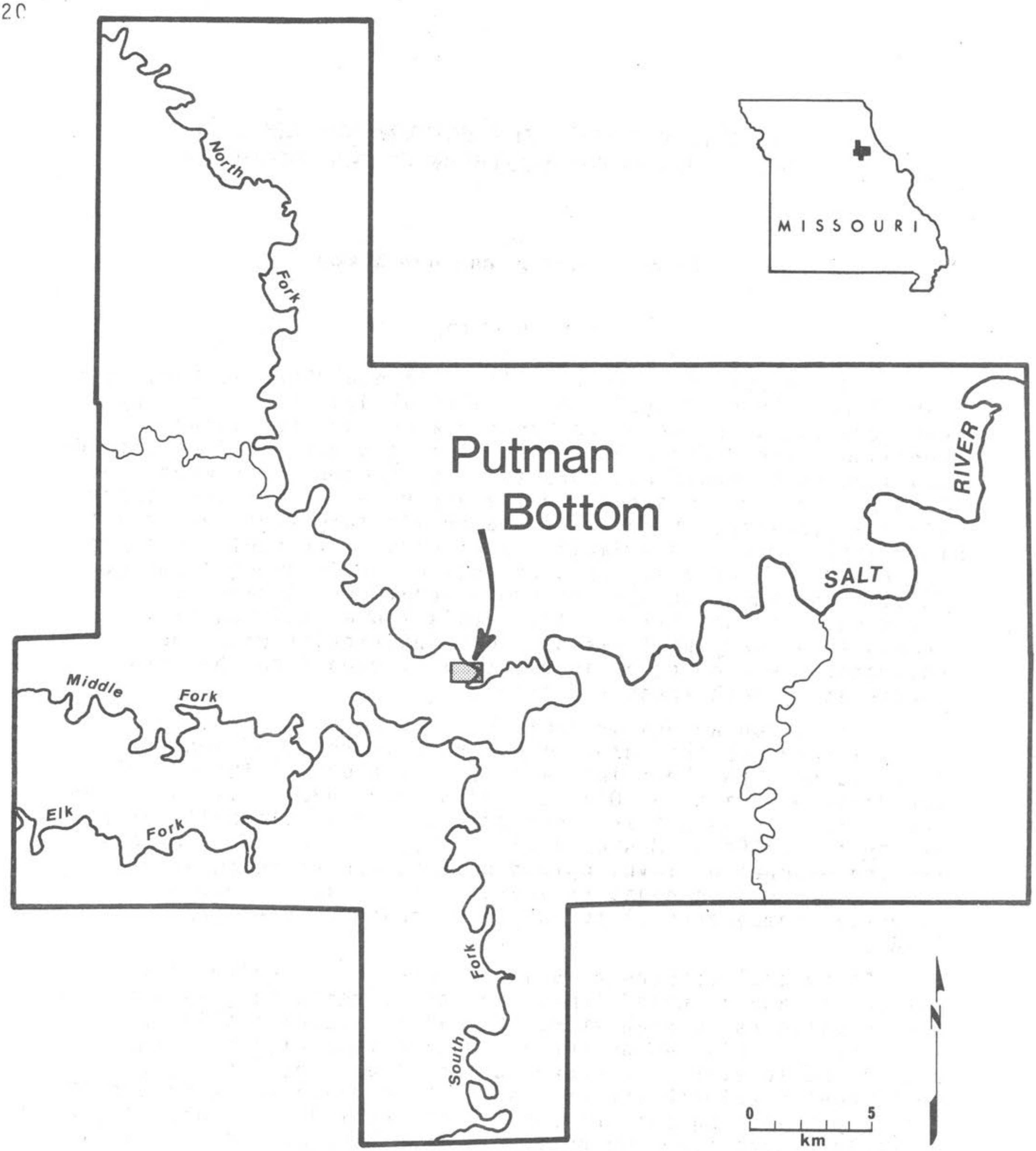

Figure 4.1. Sampling region of the Cannon Reservoir Human Ecology Project, showing the Putman Bottom locality.

Ecology and Response

Using concepts adapted from ecological theory, O'Brien and Warren (1979) have evaluated the environment of the middle Salt River valley and constructed a hypothetical model of adaptation and cultural development among prehistoric hunter-gatherers in the region (O'Brien 1977). Their discussion of expected human locational responses to patterns and magnitudes of resource distribution is pertinent to the problem dealt with here. Citing works by Wiens (1976) and others, they perceive the environment as an assemblage of patches. Patches are defined as intersecting subsets of biotope space which are distinguishable by ecological criteria, and are separated by selective discontinuities which influence the distributions, interactions, and adaptations of organisms. Paralleling this concept, ethological theory indicates two forms of grain response - fine grain and coarse grain - may be expected among mobile organisms which occupy different kinds of patches (MacArthur and Pianka 1966; Pianka 1974). The former is a generalist strategy in which resources are exploited in direct proportion to their relative abundance, while the coarse grain response is a specialist strategy in which populations exploit patches selectively.

Incorporation of these concepts into models of prehistoric locational behavior requires adoption of a meaningful interactive link between patch composition and grain response. Floral species diversity, a readily quantifiable factor, is suitable for this role. It theoretically covaries in space and time with a variety of ecological factors pertinent to structures of human extractive strategies (Osborn and Falk 1977). Chief among these associations are direct correlations with levels of species dispersion and levels of diversity among faunal species (Margalef 1968; Whittaker 1972). Together, these associations indicate that aggregating plant and animal species are unlikely in patches with high species diversity, but are dominant components of homogeneous habitats. As a result, human strategies of resource extraction can be expected to vary among patches expressing different levels of diversity, and we can infer that this variation will in turn affect mobility requirements, site locations, and composition of artifact assemblages.

Two dimensions of ecological variability - patch composition and patch arrangement - are of critical importance to models of locational behavior in the Cannon region (O'Brien and Warren 1979). Several lines of evidence indicate that significant variability in the dimension of patch arrangement was historically present not only between the prairie and forest biomes, but within them as well (Warren and O'Brien 1979). Significantly, this variability is best modeled as a series of narrow concentric bands which parallel courses of major streams, have V-shaped profiles in tributary valleys, and are aligned perpendicular to downslope axes of surface strike (Warren 1976, 1979; Watson 1979). Of equal importance is the fact that the Salt River has a fairly narrow valley in the project area which rarely exceeds about five kilometers in width. Thus, sedentary resources in all zones were within easy reach of resident groups located anywhere in the region. Given minimal travel investment, most procurement tasks could be completed within the span of a single day. Therefore, residential sites of mobile-sedentary groups did not require direct access to immobile resources. Instead, settlements could be centrally located with respect to resource needs while simultaneously occupying comfortable localities with convenient access to water, fuel, and avenues of intergroup contact.

The dimension of patch composition, when reduced to the vector of floral diversity and examined in concert with the dimension of patch arrangement, ties together our model of Cannon ecological variability and allows us to derive a locational hypothesis for logistical extractive sites (O'Brien and Warren 1979). First, it must be emphasized that the patch concept referred to earlier is, in the Cannon region, most appropriately applied at the biome level of abstraction; variability at the species level is more accurately modeled as a series of independent Gaussian continua which peak in relative abundance at many points along environmental gradients (McIntosh 1967; Whittaker 1967). Accordingly, floral species diversity in the Cannon region, as indicated by 19th century General Land Office records (Table 4.1), increases continuously along a drainage class gradient which ranges from level upland prairies to flood plain forests. Floral equitability or evenness (a measure of variance among species importance values; see Whittaker 1975:95) correlates directly with species diversity (*r* = .91), while the Simpson index of dominance concentration (a measure of relative dominance among abundant species) correlates inversely with both diversity (*r* = -.78) and equitability (*r* = -.93).

Given the previously cited correlations of floral diversity with levels of population dispersion and faunal diversity, O'Brien and Warren (1979) conclude that biota in the Cannon region graded from aggregated and specialized forms in upland prairie contexts to dispersed and varied forms in flood plain forest contexts. Important here is an extension of this model: (1) upland resources suitable for human exploitation were relatively few in kind but quantitatively abundant, and (2) lowland resources were qualitatively diverse but limited in quantity. Because extractive sites are expected to vary logistically with distributions and quantities of exploitable resources, O'Brien and Warren (1979) hypothesize that "coarse-grained responses predominated in uplands, fine-grained responses predominated in lowlands, and intermediate or mixed responses occurred in intervening areas."

Table 4.1. Floral Species Diversity, Equitability (Shannon-Wiener Index), and Dominance Concentration (Simpson Index) along a Biome-Drainage Class Gradient Ranging from Prairie (first column) to Upland Forest (second column) to Flood Plain Forest (right column). Based on General Land Office Bearing Tree Data (see Warren 1976).

	PRAIRIE	FOREST				
VARIABLE	DC1-5	DC1	DC2	DC3	DC4	DC5
NUMBER OF SPECIES (S)	9	10	19	25	25	25
SPECIES DIVERSITY (d)	4.3	4.1	6.8	9.3	9.9	10.7
EQUITABILITY (H')	.45	.59	.72	.74	.90	1.08
DOMINANCE CONCENT. (C)	.56	.33	.28	.32	.22	.12

In uplands, where limited ranges of exploitable resources clustered locally in abundance, they deduce that logistical sites are small, relatively uncommon, and are distributed nonrandomly. Because logistical sites reflect small ranges of task-specific activities, it is further expected that intrasite and intersite variability among upland components is fairly low. In lowlands, where diverse ranges of exploitable resources were scattered homogeneously and in limited quantities, logistical sites should be small, relatively abundant, and spatially dispersed, with either random or uniform distributions. Because the range of lowland procurement tasks was broad, it is also expected that levels of intersite variability are high, while variability within sites is low.

Hypothesis and Objectives

The primary objective of this paper is to test one aspect of the settlement pattern model. The proposition states that lowland settings, which contained varied and dispersed natural resources, are characterized by functionally diverse archeological assemblages. Together, the ecological dimensions of patch composition and patch arrangement imply that residential and logistical sites both occur in bottomlands; the former in situations which maximize domestic considerations, and the latter in a variety of contexts conditioned by distributions of desired resources.

To test this hypothesis we examine lithic technological variability among sites within one fairly homogeneous bottomland locality. The data base consists of a series of artifact samples collected from the surfaces of 20 sites, using the "siteless survey" approach to surface collection discussed by Dunnell and Dancey (1979). Technological patterns are isolated and then evaluated in light of temporal, spatial, and surface magnitude variables in order to derive an empirical hypothesis which explains observed associations. These operations are facilitated by the use of multivariate statistical techniques which:

1. define intersite relationships on the basis of technological patterning;
2. detect significant associations of technological variables among groupings of similar sites; and
3. identify covarying technological, contextual, and surface magnitude variables capable of providing insights into relevant behavioral associations.

Implications of the empirical hypothesis are then tested, and inferences are compared with deduced expectations to evaluate their validity.

METHODS

Surface collections reported here were conducted in the Putman Bottom locality, a level to moderately sloping bottomland terrace and flood plain bench in Monroe County, Missouri (Fig. 4.2). Occupying a large slipoff slope inside a meander of the North Fork of Salt River, the locality was heavily timbered during the early 19th century and lay about four kilometers from the nearest extensive patch of upland prairie.

Collection Bias

Collections were conducted in May and June, 1979 and covered a 43.1 ha area (Fig. 4.2). Although the bottom lay fallow when collected, it had been plowed the previous year and had generated only a sparse cover of young weedy regrowth. As a result, ground surface visibility was consistently high. Precipitation since cultivation had been sufficient to seal the surface soil and reduce micro-relief of the ground surface (in terms of both random roughness and oriented roughness) to near zero (see Burwell _et al_. 1966). Thus, some artifacts exposed at one point or another during the micro-erosion process were undoubtedly buried, perhaps at a disproportionate rate biased by the size and shape of different morphological classes. Sheet erosion was evident in three areas (sloping terrace face near Stations 16 through 19; ravines near Stations 13 and 27) and probably caused some downslope movement of artifacts. Mechanical disturbance was caused by a narrow field road which entered the area from the west and transected artifact scatters near four collection stations (17 through 19, and 27). In sum, modern erosional and cultural processes have probably both affected distributions and exposures of surface materials in Putman Bottom. However, it also appears that micro-erosion, the process of greatest concern to this particular study, had a uniform influence on the sample at hand and will not greatly hinder intersite comparisons.

Field Techniques

Two intensive collection techniques were used to recover surface materials: the "point provenience" and "block provenience" procedures (see Miskell and Warren 1979). The point provenience technique plots all artifacts individually and has proved to be a rapid and efficient approach on sites with low surface material densities. Three steps are involved. First, collectors intensively search for cultural materials in contiguous one-meter wide corridors, flagging all artifacts with surveyor pins. Second, a transit is used to determine the

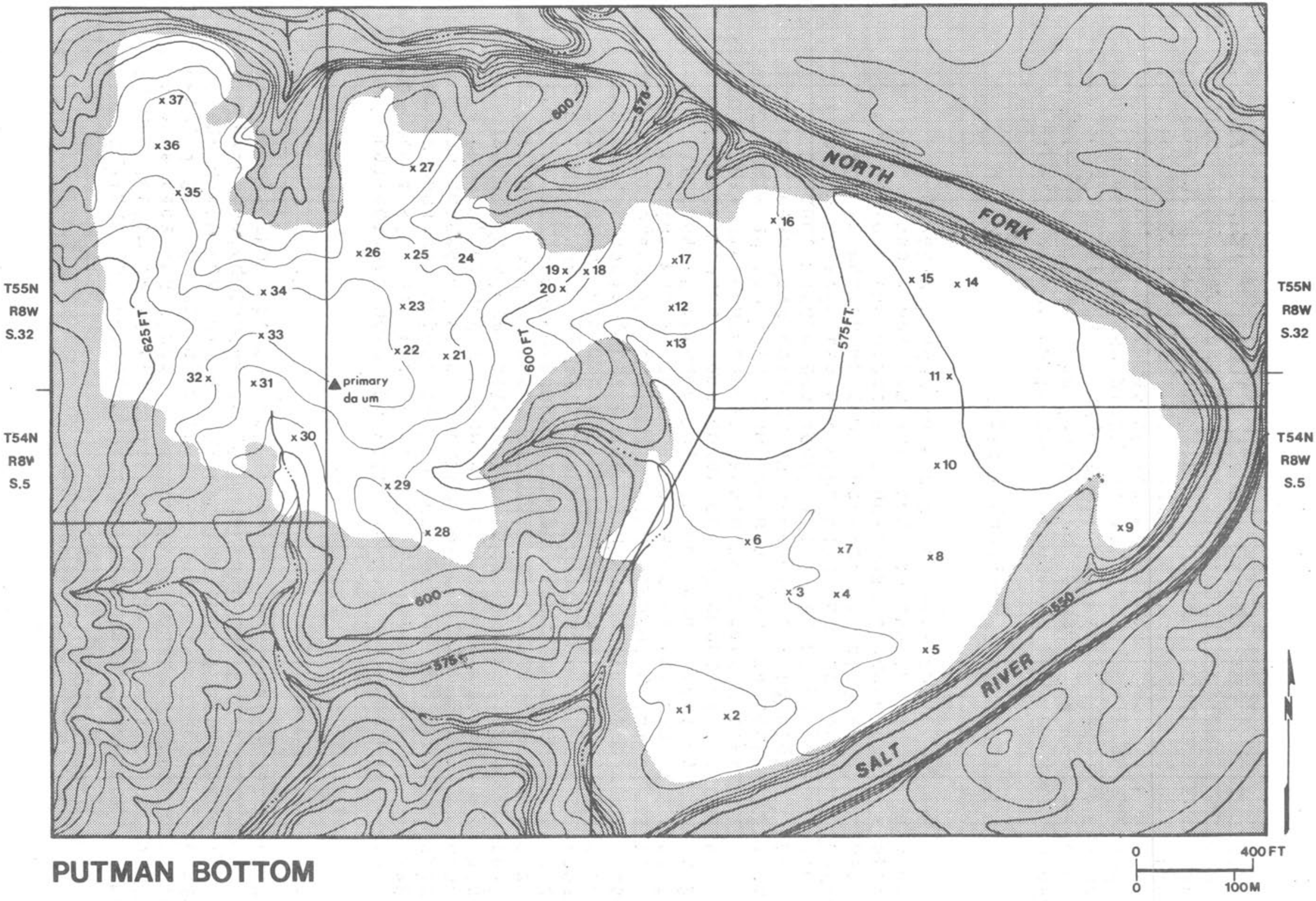

Figure 4.2. Map of the Putman Bottom locality, showing stations (1-37), extent of collection area (unshaded portion), and boundaries of scatter maps (Figs. 4.3-4.6).

bearing and distance of each item from local datum. Thirty-seven of these local data, termed stations, were established in Putman Bottom (Fig. 4.2). Finally, all artifacts are collected and labeled.

The block provenience technique employs an arbitrary grid of 2 x 2 m squares, and proveniences all artifacts by lot inside each square. This approach is preferred on sites with high surface material densities. It was employed in Putman Bottom only in the vicinity of Station 27, where 1,946 squares were collected in an area with dense scatter.

Artifact Classification

Two systems of artifact classification have been applied to Putman materials: size and morphological class (Curry 1979). Both classification systems are comprised of technological partitions. Therefore, neither is suitable for evaluating specific functions of artifacts. However, functional inferences can be derived from morphological attributes, and these hypotheses can be tested using an additional classification system designed specifically to evaluate function (see Miskell and Warren 1979; functional analysis of Putman artifacts is currently underway).

The size grade classification is comprised of four arbitrary categories. Artifacts were passed through a graduated series of wire mesh screens with mesh intervals of one inch, one-half inch, and one-quarter inch. Size identifications were assigned according to the mesh interval which stopped the flow of each artifact (1", 1/2", 1/4", <1/4").

The morphological classification includes 45 technological categories (Miskell and Warren 1979). Thirty-six of these refer to unformed chipped stone artifacts. Included are nine morphological groups (COREs; core REJUvenation flakes; core SHATter; PRIMary decortification flakes; SECOndary decortification flakes; tertiary CHUNks; TERTiary flakes; TRIMming flakes; and SHARpening flakes), each of which is subdivided into four categories based on the presence or absence of heat treatment and retouch flake scars aligned in a continuous series along the intended working edge of an artifact (UN-heat treated and NOnretouched; UN-heat treated and REtouched; HEat treated and NOnretouched; HEat treated and REtouched). Also included are five formed chipped stone categories (PROJectile POINts; BIFACEs; DRILs and PERForators; FORMed SCRApers; MISCellaneous FORMed cryptocrystalline), CERAMICS, and three categories of ground stone (UNFOrmed GROUnd stone; MISCellaneous GROUnd stone; FORMed GROUnd stone).

Analytical Techniques

Several complementary analytical techniques were used to identify systematic sources of variance within and between the

Putman data sets. Multivariate procedures, which have the advantages of being both comprehensive and heuristic, facilitated the ordination and hierchical arrangement of cases.

Two independent lines of investigation were followed. The first used artifact size and technological class frequencies to define intersite relationships and to isolate associational trends among variables, on the basis of variable patterning within cases. Accordingly, values were standardized by case to eliminate magnitude variability, and Q-mode applications were used for all analyses.

Frequencies may be qualified as discrete ratio scale measures suitable for a number of multivariate manipulations (Anderberg 1973). Procedures used here are non-parametric, or distribution free, yet some interpretations assume multivariate normality of variables (Doran and Hodson 1975). This assumption was tested using Veldman's (1967) program RELATE to compare coordinates produced in three dimensions by varimax rotated non-metric and metric multidimensional scaling procedures. Variation between these respective rank order and euclidean distance techniques indirectly reflects any existing multivariate abnormality. Results obtained for three data sets (artifact class; size grade; class-size) are expressed as matrices of cosines among axes of dimensionality and as cosines among pairs of test vectors (Table 4.2). These cosines, interpretable as correlation coefficients (Harman 1960:62), indicate that outputs from the two scaling procedures are nearly identical, and we conclude that the magnitude of multivariate abnormality present within variables is not sufficient to affect interpretations.

Cluster analysis was used to group sites by relative degrees of case similarity. Program TAXON, a sequential agglomerative hierarchical clustering technique (Rohlf, Kishpaugh, and Kirk 1972), generated phenons using an unweighted pair-group method with arithmetic averages (UPGMA). Cophenetic correlation coefficients (artifact class, $\underline{r}_{coph} = .88$; size grade, $\underline{r}_{coph} = .80$; class and size, $\underline{r}_{coph} = .75$) signify fair to good fits between original and implied association matrices, and we conclude that the samples are suitable for hierarchical arrangement.

Non-metric multidimensional scaling was also used to evaluate intercase relationships. This procedure, first proposed by Shepard (1962), calculates cartesian coordinates for cases in reduced dimensionality whose intercase distances are monotonically related to distances among cases in n-dimensional euclidean space. The TORSCA-9 program of Young (1968) was used to generate coordinates in five- through one-dimensional space based on distance matrices obtained from the utility program DSQDSQ (Benfer 1971; Heisler 1975). Stress levels, measures of disparity between original and reduced distance matrices,

Table 4.2. Tests of Multivariate Normality of Artifact Frequencies Using RELATE, a Factor Structure Comparison Program, to Compare Case Coordinates Derived from Non-Metric vs. Metric Multi-Dimensional Scaling Procedures (TORSCA-9; 3-Dimensional Solutions).

	TRACE (%)	COSINES AMONG AXES OF DIMENSIONALITY				COSINES AMONG PAIRS OF TEST VECTORS		
			1	2	3	n	$\bar{x}$	o
ARTIFACT CLASS	84.6	1	.97	-.17	.14			
	(100)	2	.18	.98	-.02	12	.93	.09
		3	-.14	.05	.99			
			1	2	3	n	$\bar{x}$	o
SIZE GRADE	226.9	1	1.00	0.00	0.00			
	(100)	2	0.00	1.00	0.00	20	1.00	.00
		3	0.00	0.00	1.00			
			1	2	3	n	$\bar{x}$	o
CLASS + SIZE	223.3	1	1.00	.04	0.00			
	(100)	2	-.04	1.00	.03	20	.99	.01
		3	0.00	-.03	1.00			

indicate optimal solutions ($s < .05$) occur in two dimensions for artifact class ($s = .04$) and size grade ($s = .01$), and in three dimensions for class and size combined ($s = .04$).

Trends among variables were evaluated using two alternate approaches: principal components analysis of complex structure (size-class data set) and graphic representation of simple structure (artifact class and size grade data sets). Principal components analysis (in Q-mode) is an ordination technique that: (1) reduces case redundancy by redefining case relationships along uncorrelated underlying axes (factors) which account for diminishing amounts of intercase variance, and (2) generates factor scores which identify the relative contribution of each variable to each factor. All factors with eigenvalues greater than or equal to 1.0 were extracted and orthogonally rotated (varimax criteria) using the BMD-P4M program of Frane and Jennrich (1977). Graphic representation (of mean values within phenons) was used when intercase relationships were essentially unilinear, as indicated by principal components extraction of only one factor (artifact class data) or strong alignment of cases along one dimension by non-metric multidimensional scaling (size grade data).

A second line of investigation introduces the dimensions of time, space, and case magnitude in order to isolate covarying external factors which would enhance the interpretive potential of technological results. Accordingly, discriminant function analysis was used to determine whether an independent set of variables (sensitive to site context and site magnitude) could form functions capable of discriminating between groups of technologically similar sites (cluster analysis phenons derived from artifact class, size grade, and size-class data sets). Poor discrimination, evident when errors are common in jackknife classifications (see below), indicates predefined groups are not separable within the measurement space defined by discriminant variables, and implies that either too few or too many groups have been preidentified (Anderberg 1973). Because of this possibility a stepwise discriminant procedure was selected which would, even in the event of poor overall discrimination, identify the discriminatory potential of individual variables (BMD-P7M; Jennrich and Sampson 1977).

MATERIALS

Surface collections in Putman Bottom yielded a total of 15,969 artifacts. Distributions of these objects (Figs. 4.3 to 4.6) indicate that concentrations vary widely in size, density, and location. For the purposes of comparative analysis, artifact concentrations surrounding the 37 stations were consolidated into 20 cases (A-T) on the basis of spatial contiguity of artifacts shown on large scale distribution maps.

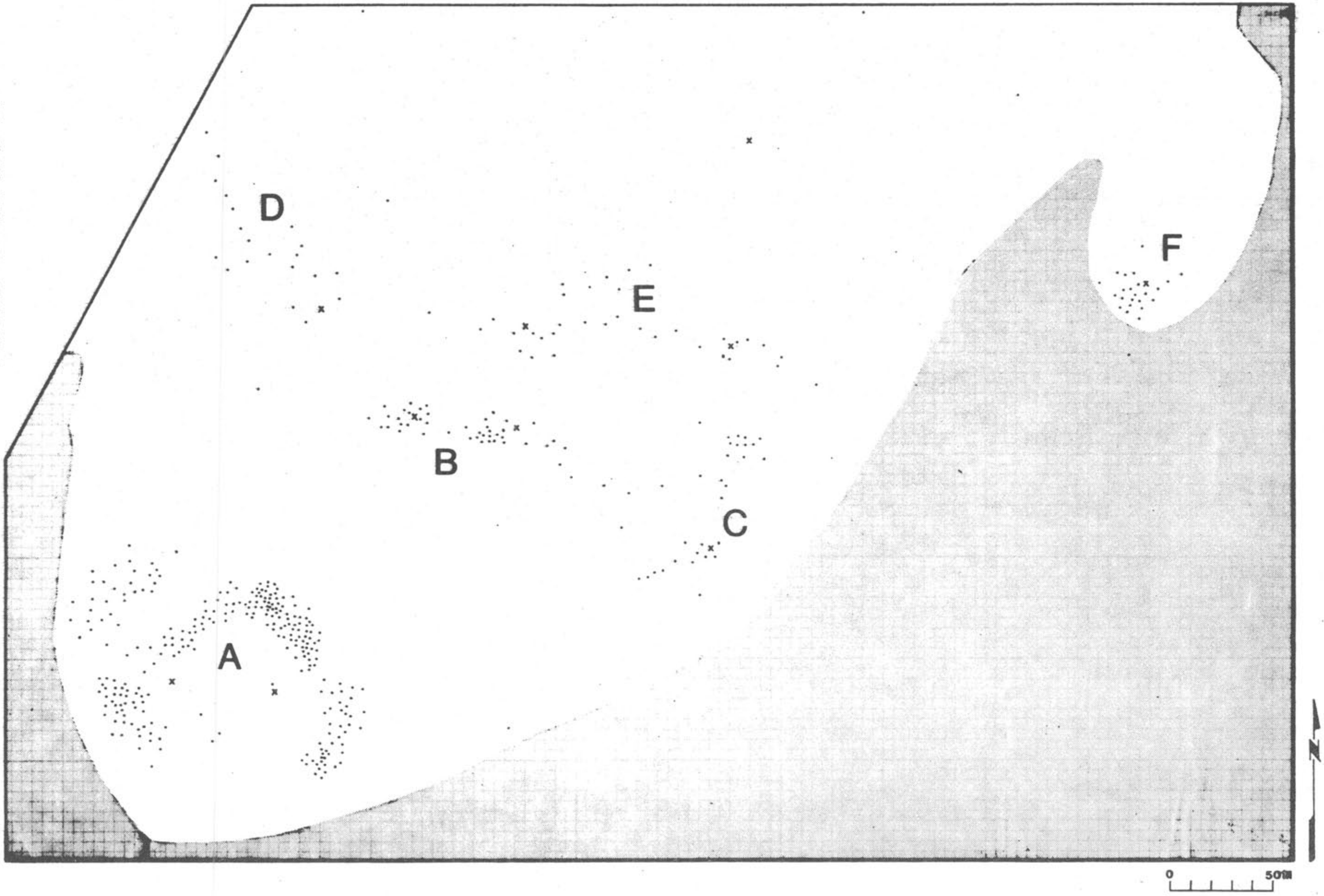

Figure 4.3. Map of artifact scatter in southeast portion of Putman Bottom. Each dot represents 4 artifacts; letters denote sites.

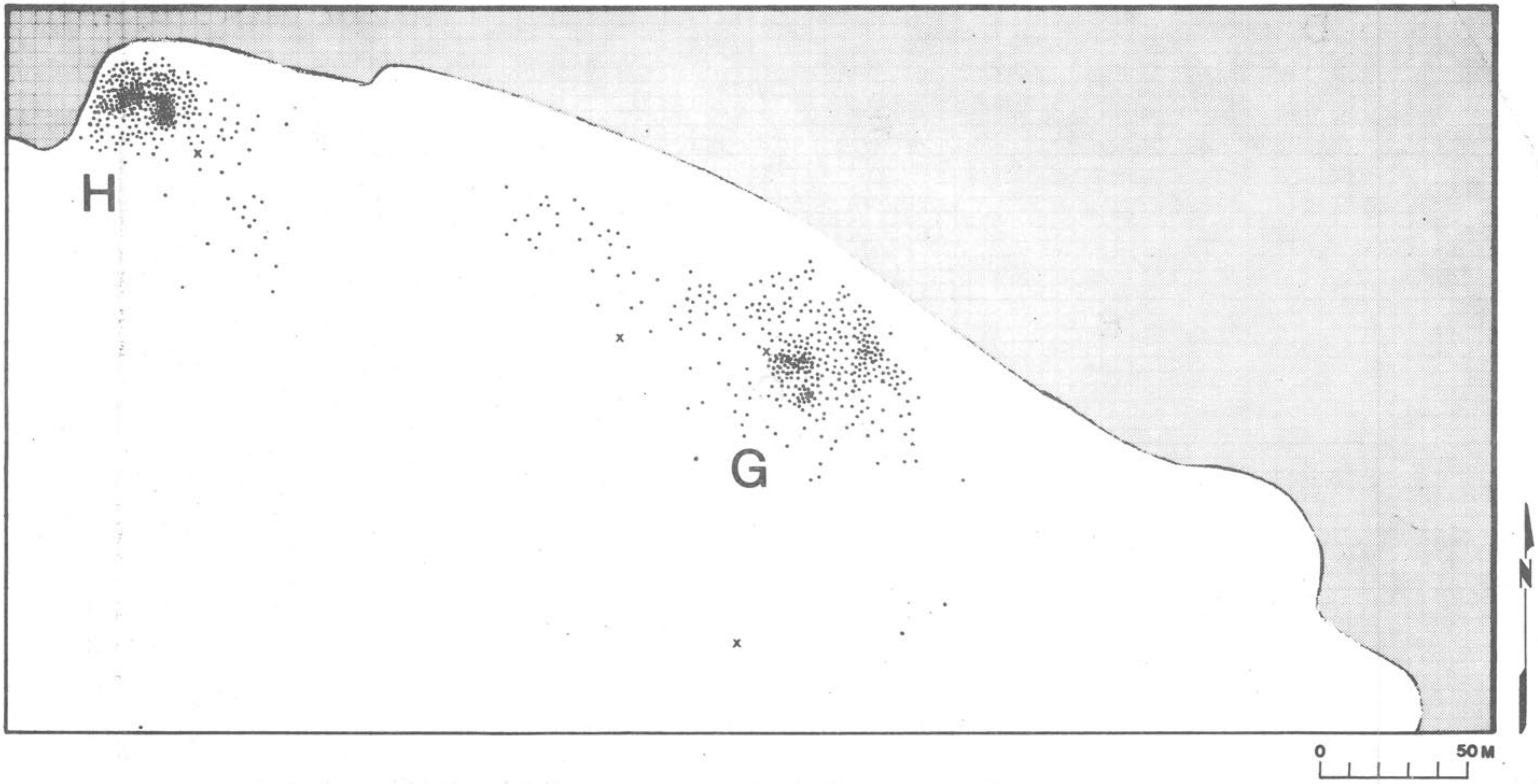

Figure 4.4. Map of artifact scatter in northeast portion of Putman Bottom. Each dot represent 4 artifacts; letters denote sites.

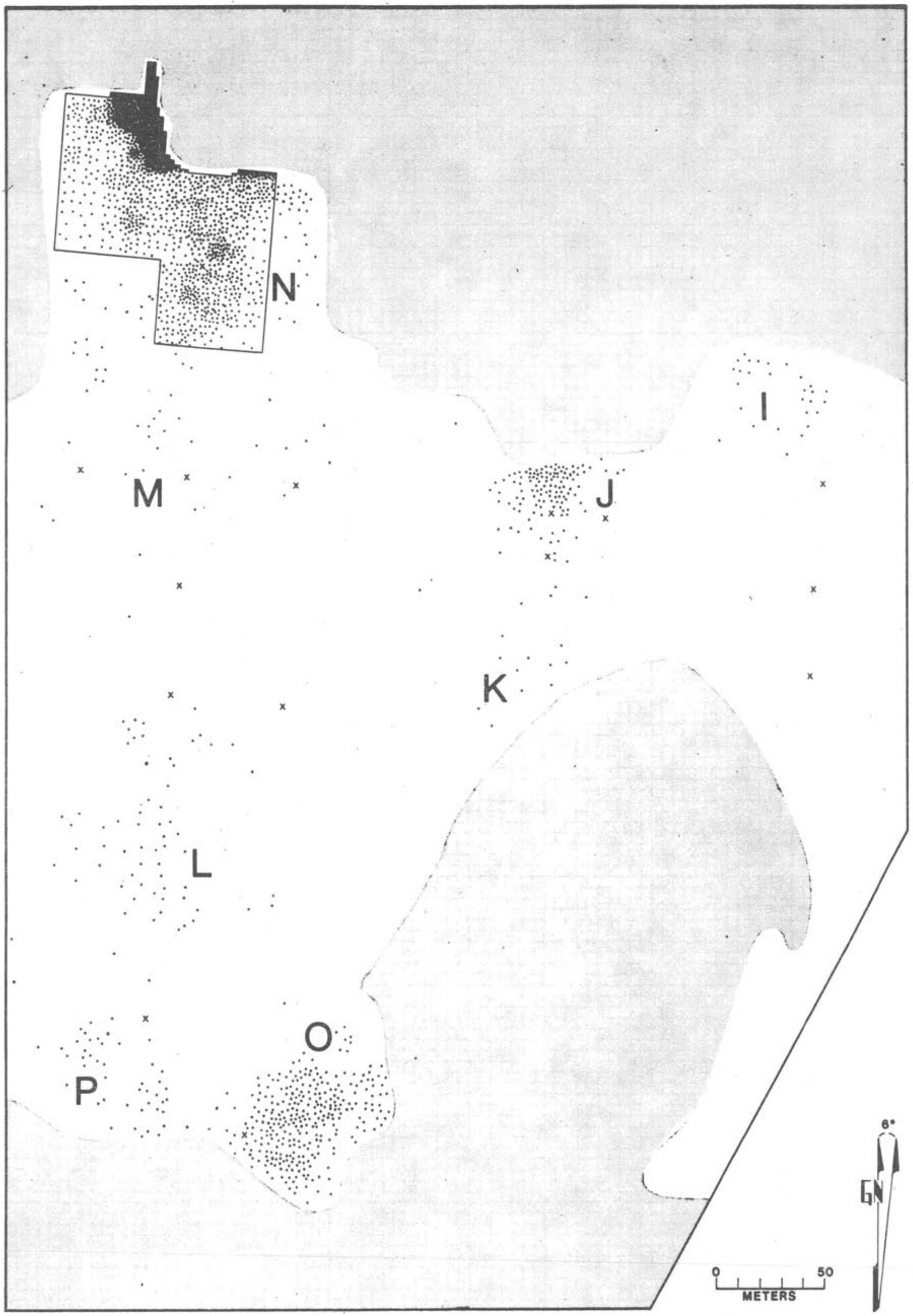

Figure 4.5. Map of artifact scatter in central portion of Putman Bottom. Each dot represents 4 artifacts; letters denote sites; line encloses block provenience grid at site N.

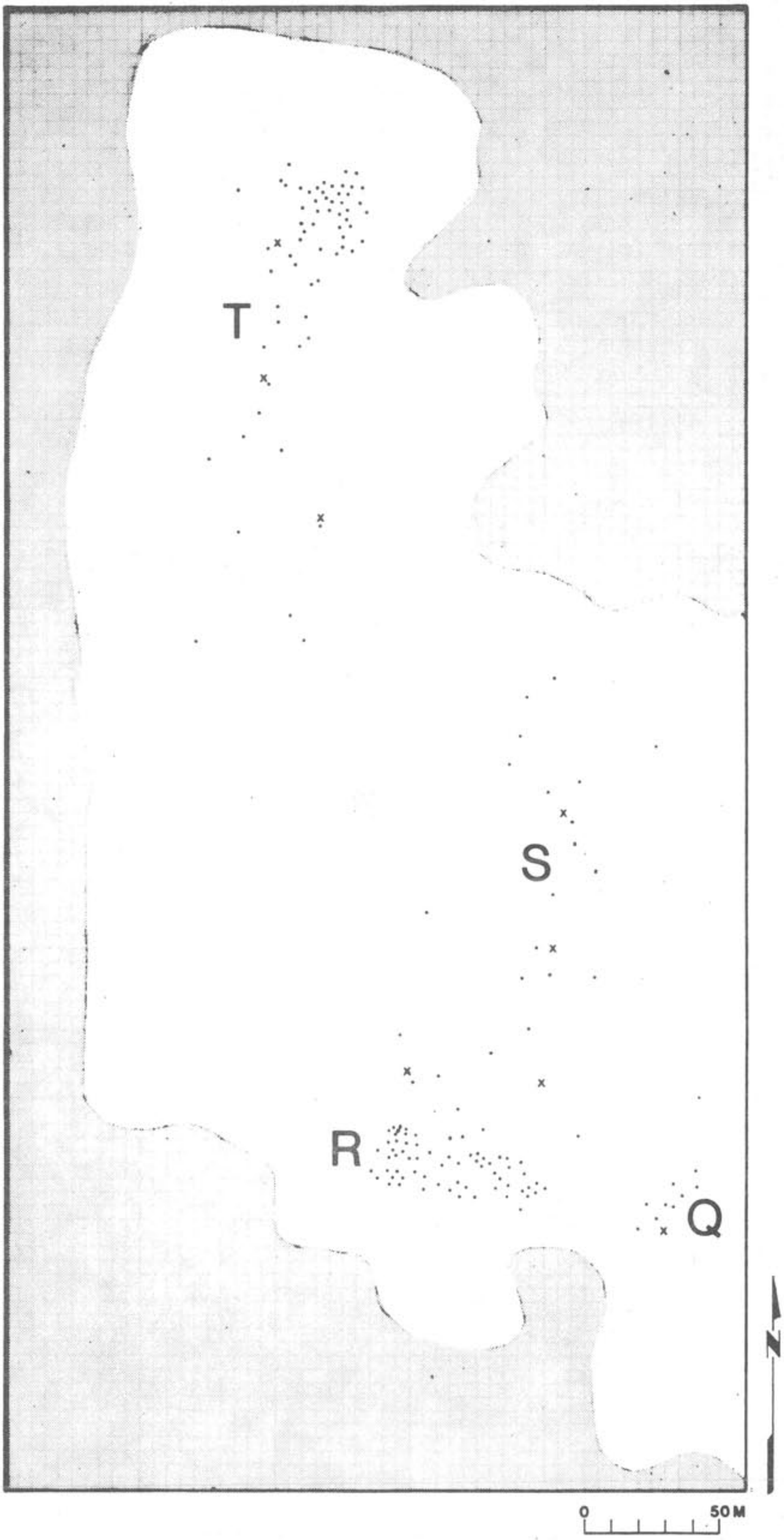

Figure 4.6. Map of artifact scatter in west portion of Putman Bottom. Each dot represents 4 artifacts; letters denote sites.

Parts of six sites (H, I, J, N, O, P) lay outside the collection area and samples from these are spatially biased.

Raw frequencies of artifact class and size grade variables are presented in Table 4.3. Because samples vary greatly in size ($\bar{x} = 798 \pm 1,747$) and interpretive errors are expected to increase with decreasing contingency cell values, sites were excluded from analysis if their mean cell values fell below an arbitrary level of 4.0. Thus only 12 cases were fit for artifact class analysis (A, B, G, H, J, L, M, N, O, P, R, T), while all 20 cases were suitable for size grade and size-class manipulation. Heterogeneity within the size grade and artifact class data sets was evaluated using chi-square tests. Both were found to vary significantly from uniformity at alpha = .001 [size grade, $x^2 = 2,166.4$, *df* = 57, $z_Q = 55.2$; artifact class, $\chi^2 = 2,024.4$, *df* = 140, $z_Q = 46.9$ (*note*: several columns and rows were combined to obtain acceptable cell sizes in the artifact class data set; see Thomas 1976:298)].

Values for 35 time-space-magnitude variables are presented in Table 4.4. The temporal dimension (columns 29-33) is defined by frequencies of projectile points, which were assigned to time-culture periods on the basis of stylistic associations with point types excavated from stratified deposits at the Pigeon Roost Creek site (Teter and Warren 1979). A components variable (c. 34) denotes the number of time-culture periods represented by point styles within each site. The spatial dimension (see Warren 1979) is reflected in a series of locational variables including elevation (meters AMSL; c. 4); local relief (m; cs. 5, 22, 28); distance (m; c. 6) and direction (cs. 23-27) to maximum local relief; vertical and horizontal distances (m) to nearest stream (cs. 7-8) and nearest perennial stream (cs. 10-11); rank order of nearest stream (c. 9); areas of local drainage classes (cs. 12-14); slope dip (c. 15) and strike (c. 16); soil series (cs. 17-20); and distance to ecotone (c. 21). Magnitude variables include sample size (c. 1); mean artifact density [/m(1000); c. 2]; maximum artifact density [/m(100); c. 3]; and site size (m^2; c. 35). Dummy variables (cs. 17-20, 23-27) were standardized by row; all other variables were standardized by column.

INTERSITE RELATIONSHIPS

Technological relationships among sites were determined by cluster analysis and non-metric multidimensional scaling analysis (NMMDS) of artifact patterns. Results are presented in two- and three-dimensional plots of cases, where intercase distances reflect relative degrees of similarity or dissimilarity among sites, and clusters of similar sites are circumscribed by linkage lines.

A configuration of 20 sites, plotted on the basis of size

SITE	UNNO CORE	UNRE CORE	HENO CORE	HERE CORE	UNNO REJU	UNRE REJU	HENO REJU	HERE REJU	UNNO SHAT	UNRE SHAT	HENO SHAT	HERE SHAT	UNNO PRIM	UNRE PRIM	HENO PRIM	HERE PRIM	UNNO SECO	UNRE SECO	HENO SECO	HERE SECO	UNNO CHUN	UNRE CHUN	HENO CHUN	HERE CHUN
A	6	2	0	0	9	16	1	1	8	4	0	0	13	0	0	1	61	20	13	9	126	28	30	2
B	1	0	0	0	0	1	0	0	1	0	0	0	2	0	0	0	14	9	4	0	16	8	2	1
C	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	20	11	1	1	6	10	0	2
D	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	7	10	1	1	1	10	0	0
E	6	0	1	0	0	3	0	0	0	0	0	0	6	0	0	0	17	10	2	1	14	8	2	0
F	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	9	0	0	3	7	1	1
G	0	2	0	0	4	12	1	3	0	1	1	0	0	0	0	0	74	49	36	19	125	45	29	21
H	1	3	0	0	0	20	0	0	0	1	0	1	1	0	0	0	113	78	45	20	131	68	66	20
I	0	2	0	0	0	2	0	1	0	0	0	0	0	0	0	0	9	9	6	5	3	8	1	1
J	0	3	0	0	0	10	0	0	0	0	0	0	0	0	0	0	22	29	9	11	33	35	4	6
K	1	0	0	0	1	2	0	0	0	2	0	0	0	0	0	0	4	0	2	1	12	3	0	0
L	0	3	0	0	0	3	0	1	0	0	0	1	0	0	0	0	13	16	1	5	22	31	7	6
M	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	7	12	3	2	10	18	1	0
N	30	11	7	7	2	6	2	6	4	3	1	0	21	5	2	1	379	82	113	85	521	48	278	29
O	1	6	0	0	1	20	0	0	0	1	0	0	0	0	0	0	54	50	15	13	113	81	9	7
P	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	8	4	1	0	30	10	0	0
Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	2	1	10	3	3	1
R	0	1	0	0	1	2	0	0	0	0	0	0	0	0	0	0	8	3	1	2	27	25	10	4
S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	1	0	10	6	0	4
T	0	7	0	0	0	5	0	0	0	0	0	0	1	0	0	0	9	21	3	1	20	38	4	7

SITE	UNNO TERT	UNRE TERT	HENO TERT	HERE TERT	UNNO TRIM	UNRE TRIM	HENO TRIM	HERE TRIM	UNNO SHAR	UNRE SHAR	HENO SHAR	HERE SHAR	PROJ POIN	BIFA CEEE	DRIL PERF	FORM SCRA	CERA MICS	MISC FORM	UNFO GROU	MISC GROU	ONEE INCH	HALF INCH	QUAR INCH	LESS QUAR
A	451	83	151	29	4	0	0	2	21	6	8	6	5	8	0	5	1	30	2	13	190	391	471	123
B	77	18	23	10	3	1	1	0	1	2	0	0	2	1	0	0	1	1	1	2	35	83	62	23
C	28	14	9	6	3	2	0	0	0	1	1	3	1	0	0	1	0	2	0	0	28	51	30	14
D	13	14	1	4	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	24	30	11	3
E	19	6	2	3	0	0	0	0	0	0	0	0	3	2	0	1	0	7	1	2	54	36	21	5
F	27	15	6	4	0	0	0	0	3	1	1	2	0	2	0	0	0	0	0	0	19	31	32	5
G	675	131	172	86	10	1	5	0	20	2	16	8	2	1	0	2	0	12	2	0	102	483	783	199
H	361	208	104	49	10	1	1	1	9	6	2	2	2	2	0	1	0	7	2	1	173	535	509	120
I	30	26	10	7	1	0	1	0	0	0	0	0	0	2	0	0	0	3	0	0	27	47	47	6
J	166	115	38	27	4	2	1	0	7	4	3	1	3	7	0	0	0	2	0	0	73	203	222	44
K	23	7	10	0	0	0	0	0	1	2	0	0	0	1	0	0	0	2	0	0	16	43	15	0
L	101	51	29	20	0	0	1	0	5	4	0	0	0	2	0	1	0	2	1	0	56	152	112	6
M	60	38	13	9	2	0	0	0	2	3	0	0	0	1	0	0	0	4	0	0	40	70	69	10
N	2747	976	1510	366	145	56	108	31	116	38	76	57	7	12	3	7	7	4	11	2	519	1616	3591	2196
O	440	314	56	46	7	4	1	0	11	13	7	2	2	9	0	0	0	4	3	0	188	526	529	47
P	94	24	10	4	1	0	0	0	3	3	0	0	1	0	0	0	0	1	1	0	14	64	104	15
Q	20	9	5	2	1	0	0	0	0	3	0	3	0	0	0	0	0	0	0	0	3	40	23	1
R	87	37	20	10	0	1	0	1	6	5	0	1	0	0	0	0	0	3	0	0	22	111	107	15
S	13	7	2	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	16	23	15	3
T	42	47	12	9	0	2	1	0	0	3	2	2	1	1	0	3	0	5	1	0	84	87	67	9

Table 4.3. Raw Frequencies of Surface Artifacts on 44 Artifact Class Variables and 4 Size Grade Variables (n = 20 Sites).

Table 4.4. Raw Values of 35 Time-Space-Magnitude Variables on 20 Surface Sites.

SITE	SAMP SIZE	MEAN DENS	MAXI DENS	ELEV ATON	MAXI RELF	HORI RELF	VERT STRM	HORI STRM	RANK STRM	VERT PERE	HORI PERE	DRAN THRE	DRAN FOUR	DRAN FIVE	SLOP EDIP	SLOS TRIK	FATI MASO	MARI ONSO
A	1175	332	168	175	41	500	3	100	1	6	125	3	23	23	1	1	2	1
B	203	181	64	175	32	500	6	150	6	6	150	1	27	21	1	2	2	1
C	123	87	40	174	35	500	5	75	6	5	75	1	24	24	1	2	2	1
D	68	41	24	175	21	500	3	200	1	6	250	2	24	23	1	1	1	2
E	116	43	24	175	20	500	6	150	6	6	150	1	21	27	1	2	1	2
F	87	112	40	174	29	500	5	50	6	5	50	1	21	27	1	2	2	1
G	1567	288	456	177	30	500	8	50	6	8	50	3	21	25	1	4	1	2
H	1337	709	416	177	20	475	8	50	6	8	50	0	26	23	1	3	1	1
I	127	90	84	180	20	325	11	150	6	11	150	2	29	18	1	3	1	1
J	542	303	192	183	29	500	12	225	2	14	275	3	28	18	2	3	1	1
K	74	27	16	183	27	500	14	300	6	14	300	5	26	18	5	4	1	1
L	326	77	28	189	33	450	15	250	1	20	500	12	30	7	4	2	1	1
M	189	30	28	186	33	500	11	325	2	17	350	9	24	16	2	4	1	1
N	7922	871	1531	186	32	500	11	125	2	17	250	6	28	15	1	4	1	1
O	1290	342	216	186	33	500	12	175	1	17	475	7	32	10	1	2	1	1
P	197	182	68	187	33	400	12	200	1	18	450	12	28	9	1	4	1	1
Q	67	114	28	186	31	350	12	325	1	17	550	12	32	5	3	1	1	1
R	255	178	116	187	34	500	14	275	1	18	625	19	29	1	4	2	1	1
S	57	12	20	186	33	375	14	275	1	17	500	14	28	7	3	4	1	1
T	247	90	88	184	33	475	12	125	1	15	400	9	28	12	2	3	1	1

SITE	GORI NSOL	CALW OODS	ECOT DIST	RELF ABOV	SIXT YDEG	HUNT WDEG	HUNE TDEG	TWOF ODEG	TREH UDEG	RELF BELO	LATE WOOD	MIDL WOOD	MIDL ARCH	ERLY ARCH	DALT ONPO	COMP ONEN	ESTI SIZE
A	1	1	28	35	1	1	2	1	1	6	2	3				2	3479
B	1	1	27	26	1	1	2	1	1	6	1	1				2	1119
C	1	1	27	30	1	1	1	2	1	5							1414
D	1	1	27	15	1	1	1	2	1	6							1649
E	1	1	27	14	1	1	1	1	2	6	2					1	2670
F	1	1	26	24	2	1	1	1	1	5							778
G	1	1	23	23	1	2	1	1	1	8	1		1			2	5439
H	2	1	23	13	1	1	1	1	2	8	1	2				2	4788
I	2	1	24	10	1	1	1	1	2	11							4597
J	2	1	25	15	1	1	1	1	2	14	1	1				2	3327
K	2	1	25	14	1	1	1	1	2	14							2749
L	1	2	27	13	1	1	1	1	2	20							4241
M	2	1	25	16	1	1	1	2	1	17							6362
N	2	1	24	15	1	1	1	2	1	17	4	1	1	1	1	5	13597
O	1	2	28	16	1	1	1	1	2	17	3					1	3770
P	1	2	28	15	1	1	1	1	2	18							1080
Q	1	2	28	16	1	1	1	1	2	15							589
R	2	1	28	18	1	1	1	1	2	15					1	1	1429
S	1	2	27	16	1	1	1	2	1	17							4712
T	1	2	25	18	1	1	1	2	1	15	1					1	2749

grade patterning, is shown in an abbreviated Wroclaw diagram (Fig. 4.7). Five phenons (enclosed by heavy lines) are evident at a correlation linkage level of .82. Results of the two multivariate techniques are mutually supportive: (1) the two most similar sites, I and M ($r = 1.00$), are plotted close together in Phenon III, (2) the two most dissimilar sites, N and E ($r = -.71$), are plotted farthest apart in Phenons I and V, and (3) linkage boundaries are regular and enclose progressively distant sets. Of considerable interpretive significance is the essentially unilinear configuration of cases and groups. Although a fairly high stress level (.113) was achieved by a one-dimensional NMMDS solution, all phenons can be compressed into a single axis without distorting group integrity. This implies that a continuum of size grade patterns exists on dimension one which grades consistently from site N to site E.

Three phenons are evident in a Wroclaw diagram of 12 sites, arranged by relative similarities of artifact class patterning (Fig. 4.8). Results of cluster analysis and NMMDS are again consistent; sites M and J ($r = .99$) are plotted together in Phenon II, and sites A and T ($r = .67$) are plotted far apart in Phenons I and III. Significantly, cases and phenons are once again arranged in unilinear fashion, implying that one major set of trends exists among artifact class variables. Further, comparison of case positions in Figs. 4.7 and 4.8 indicates that site configurations derived from the size grade and artifact class data sets are somewhat similar. Analysis of ordinal relationships between the two data sets, based on Spearman rank-order correlations of one-dimensional NMMDS solutions, indicates they are in fact significantly correlated beyond the .01 level of probability (12 cases: $r_s = -.72$, $df = 10$, $t = 3.3$; 20 cases: $r_s = -.70$, $df = 18$, $t = 4.2$). Importantly, this implies that the sources of systematic variance explained by the first dimensions of both ordinations are shared; i.e., an empirical relationship exists among size grade and artifact class trends.

This postulated association is supported by an ordination of an inclusive data matrix comprised of artifact class *and* size grade values (both variable sets weighted equally), where a stress level of only .04 was achieved in three dimensions. An oblique view of the resulting configuration is shown in Fig. 4.9. Seven phenons are defined at a correlation linkage level of .94. On dimensions one (X axis) and two (Y axis) the clusters form a rough arc, which varies sporadically in altitude on dimension three (Z axis). Despite these irregularities, comparison with the size and class configurations (Figs. 4.7 and 4.8) supports the contention that at least some variables within the two data sets are interdependent. Also, plots of the eight cases excluded from the artifact class ordination (C, D, E, F, I, K, Q, S) imply that they generally reflect trends in morpho-

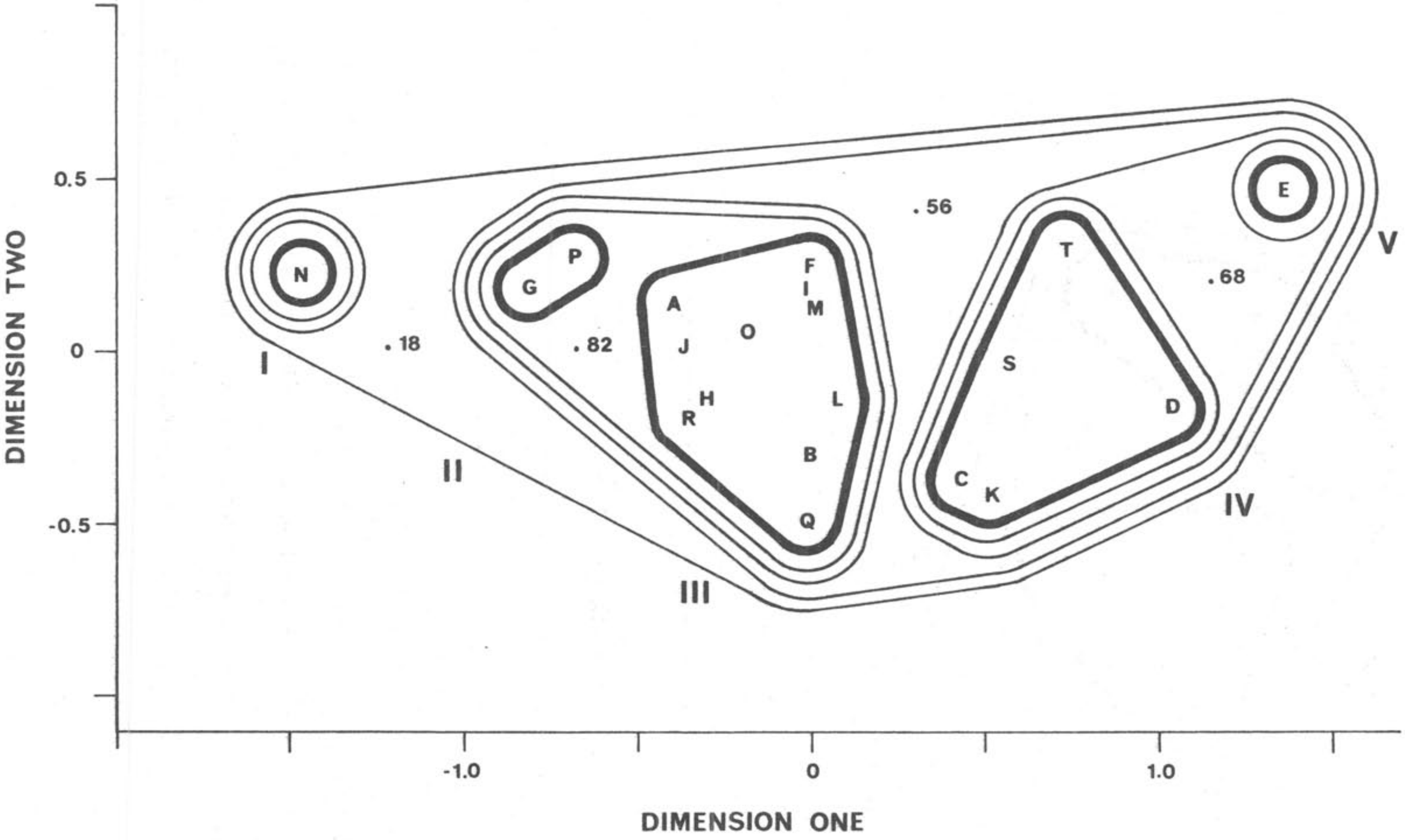

Figure 4.7. Two-dimensional non-metric multidimensional scaling configuration of intersite relationships defined on the basis of size grade patterning (n = 20; stress = .013). Heavy lines and roman numerals denote cluster analysis phenon; arabic numerals signify correlation linkage levels; letters denote sites.

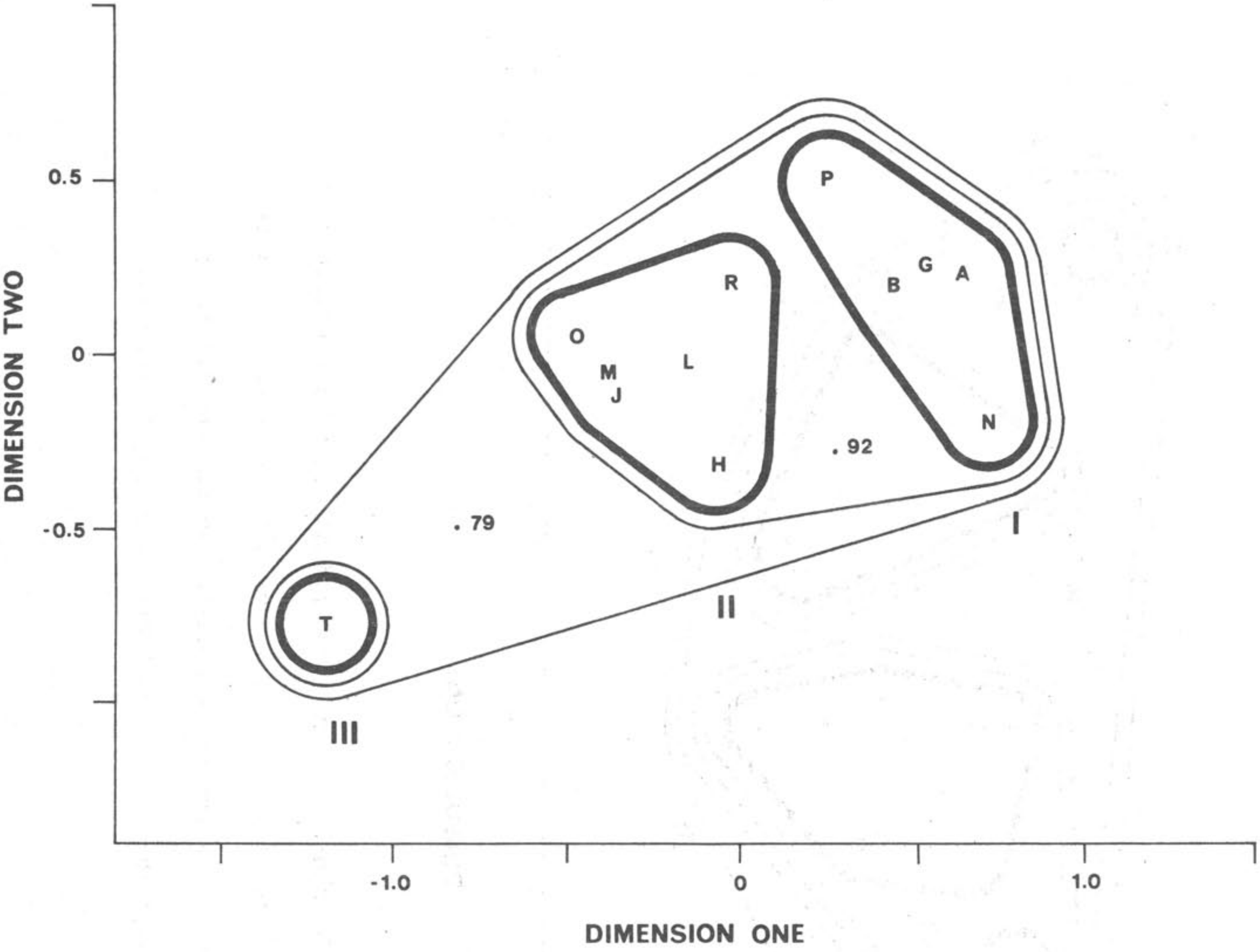

Figure 4.8. Two-dimensional non-metric multidimensional scaling configuration of intersite relationships defined on the basis of artifact class patterning (n = 12; stress = .039). Heavy lines and roman numerals denote cluster analysis phenons; arabic numerals signify correlation linkage levels; letters denote sites.

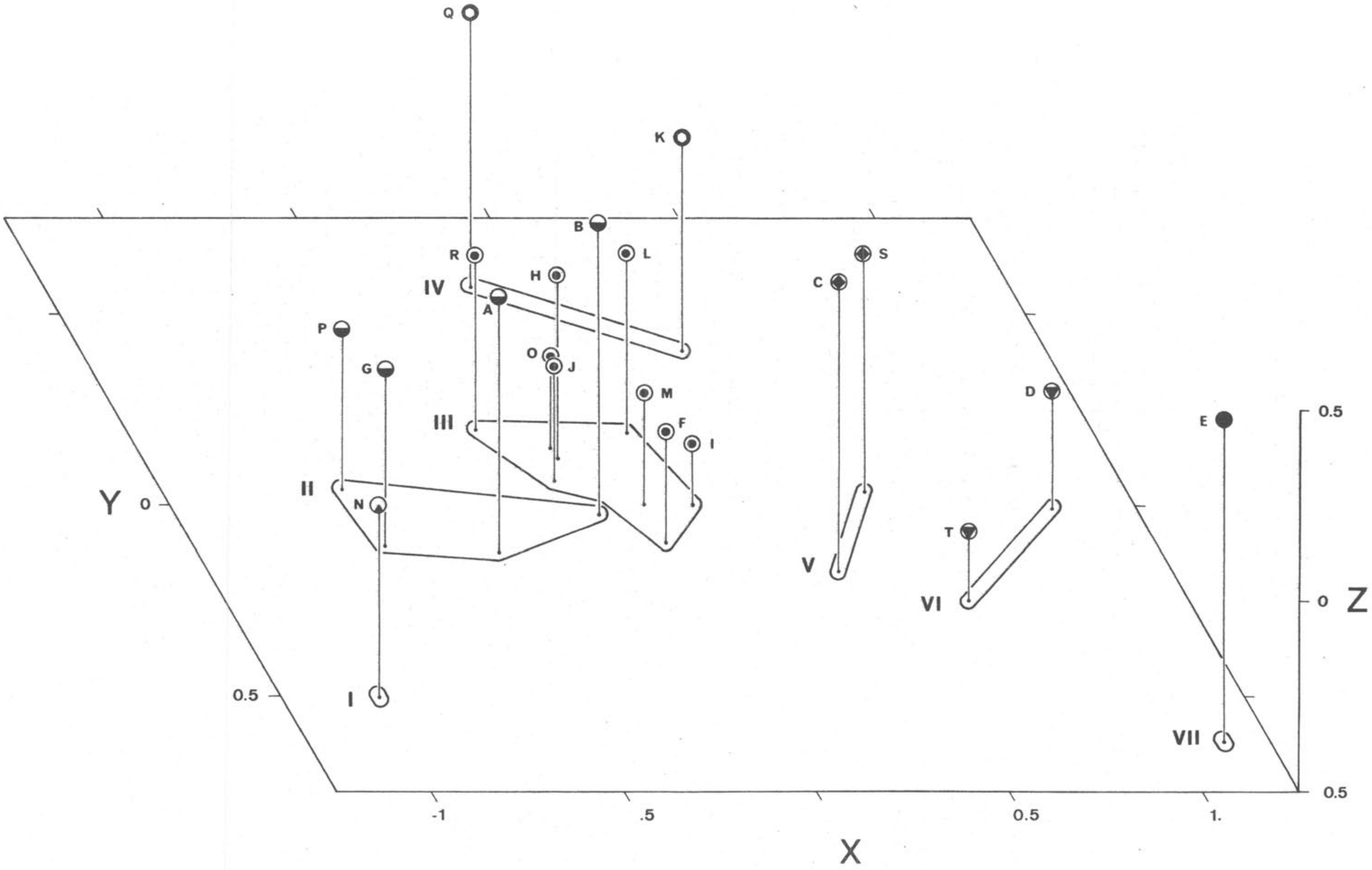

Figure 4.9. Three-dimensional non-metric multidimensional scaling configuration of intersite relationships defined on the basis of size grade and artifact class patterning (n = 20; stress = .038). Roman numerals denote cluster analysis phenons; letters denote sites.

logical patterning which are implied in Fig. 4.8.

ARTIFACT PATTERNING

Analysis of artifact patterning confirms our expectations that trends among variables shift systematically along the major axes of dimensionality defined by case ordination. The significance and directionality of specific variables are also established; for the size grade and artifact class data sets as well as the inclusive size-class matrix.

Trends among size grade variables are shown in Fig. 4.10, where mean patterns for each of the five size grade phenons are plotted in sequence (i.e., in progression along dimension one of the NMMDS configuration; see Fig. 4.7). Directionality of variables is quite obvious among the ordered phenons. They range from predominantly small artifacts in Phenon I (1/4" and <1/4") to predominantly large artifacts in Phenon V (1" and 1/2"), and intermediate clusters grade consistently between these two extremes. Variability is greatest within Phenons III and IV, where relatively large numbers of cases are grouped. Companion plots of patterns within these phenons (not presented here) indicate that variation along dimension two reflects the relative strengths of modal values. Patterns of sites Q and K, for example, are relatively peaked, while those of sites F and T are relatively flattened.

Analysis of artifact classes indicates that only a few of the 44 variables express significant <u>or</u> continuous trends among the three artifact class phenons shown in Fig. 4.8. Mean standard scores of these few variables are plotted in Fig. 4.11, where the amplitudes and directionalities of variation among phenons is readily apparent. Variables peaking in Phenon I include un-heat treated and heat treated nonretouched tertiary flakes (variables 25, 27), and un-heat treated nonretouched trimming and sharpening flakes (29, 33). At the opposite end of the spectrum, in Phenon III, modes of five variables occur: Un-heat treated retouched tertiary flakes (26), un-heat treated and heat treated retouched tertiary chunks (22, 24), un-heat treated retouched secondary decortification flakes (18), and un-heat treated retouched cores (2). Although the cultural significance of these trends is evaluated later, it can be pointed out here that several technologically meaningful associations exist among these covarying classes. Variables peaking on Phenon I represent late stages of artifact manufacturing and artifact maintenance processes, while all classes peaking in Phenon III are retouched artifacts suggestive of tool use.

Given demonstrated associations between the first dimensions of the size grade and artifact class ordinations, we expect that trends among variable patterns are also associated. Namely, the

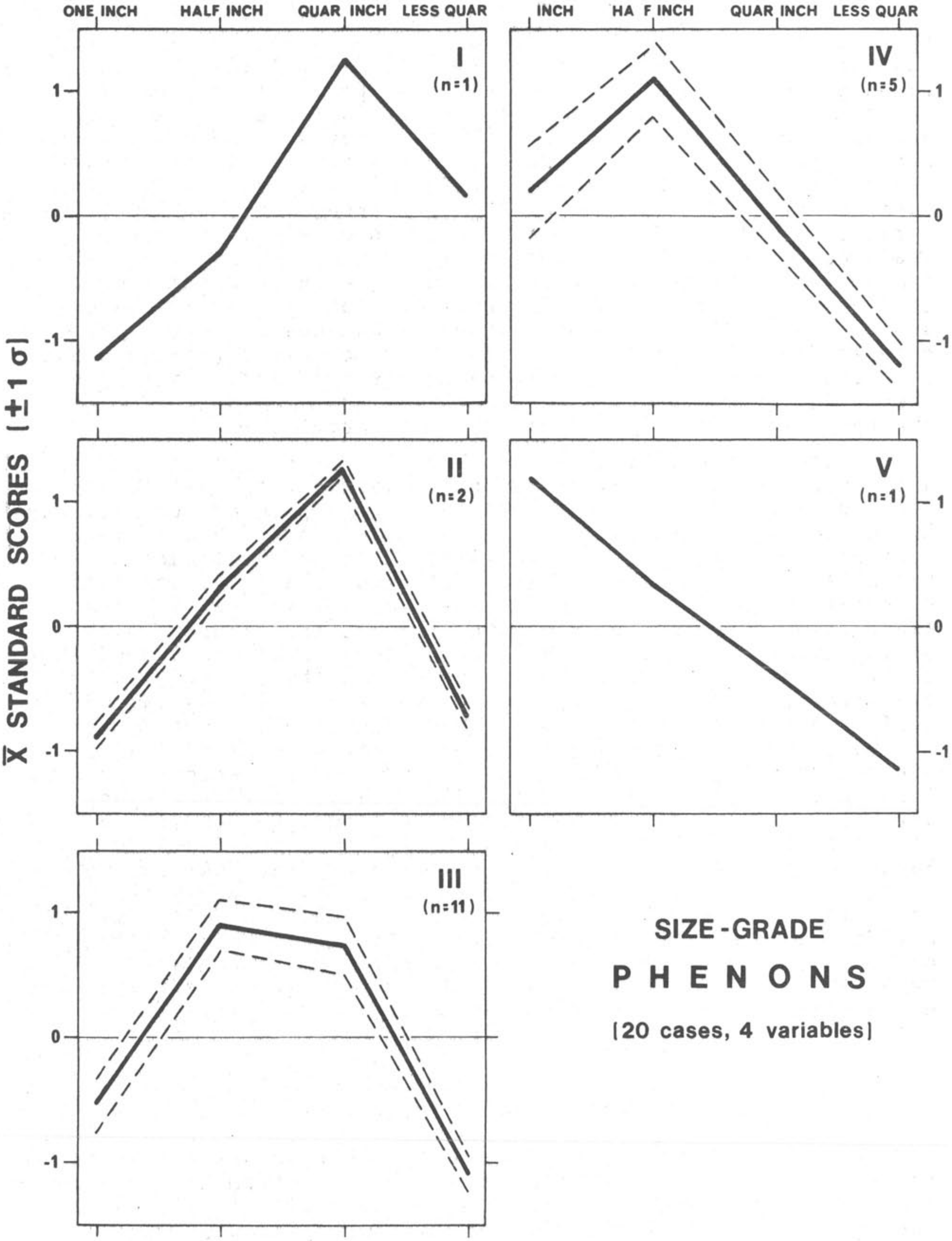

Figure 4.10. Intergroup variation of 4 size grades on 5 phenons defined on the basis of size grade patterning (n = 20 sites).

spectrum should range from assemblages dominated by small tool manufacturing and maintenance flakes to assemblages dominated by large retouched tools. To test this proposition and, at the same time, recover information lost in the artifact class analysis (due to the exclusion of eight cases), we conducted a principal components analysis (Q-mode) of the inclusive size-class data set containing all 48 technological variables. Two factors were extracted, which together account for 95% of total variance (Table 4.5). Plotted factor loadings, which are analogous to case coordinates generated by NMMDS, form a familiar arc-shaped configuration (not presented here) similar to Fig. 4.9. But because all cases are positively correlated and centroids of the two ordination techniques are not shared, case loadings are all situated in the upper right (++) quadrant of factor space in an array which ranges from site N in the lower right (highly correlated with Factor 1) to site E in the upper left (highly correlated with Factor 2).

Factor scores, measures of association between variables and factors (which have mean zero and variance of unity), are plotted in Fig. 4.12. Coordinates in this space are conditioned by two sources of variation: (1) distances of points from the centroid (0,0) reflect the quantitative strength of each variable's contribution to factor structure, and (2) bearings of points in relation to factor axes reflect the qualitative association of each variable with each factor. Thus, groups of variables with common trends are aligned radially around the centroid in linear arrays, which point out the distinguishing characteristics of each factor. Compositions of these arrays confirm our expectations. Size grade variables, all of which lie more than one standard deviation from the centroid, are ordered counterclockwise from <1/4" and 1/4" on Factor 1, through 1/2" and 1" on Factor 2 (Fig. 4.10). Artifact class variables follow suit, ranging from HENOTERT and UNNOTERT on on Factor 1, to UNRETERT, UNRECHUN, UNRESECO, and UNNOSECO on Factor 2 (Fig. 4.11). The latter variable (UNNOSECO) was not a significant component in the 12 case sample, but its position here implies it may be an important class in sites with small artifact samples (Phenons V to VII in Fig. 4.9). The failure of four other artifact classes to score highly (UNNOSHAR, UNNOTRIM, HERECHUN, UNRECORE; see Fig. 4.11) may be due to proportional error introduced by small samples, or to their relatively minor ranges of variation among groups.

CONTEXT AND MAGNITUDE

Analysis of intrasite relationships and technological patterns has demonstrated that sites in Putman Bottom can be ordered along a sequence which varies in terms of artifact size and proportions of morphological classes. We now introduce the dimen-

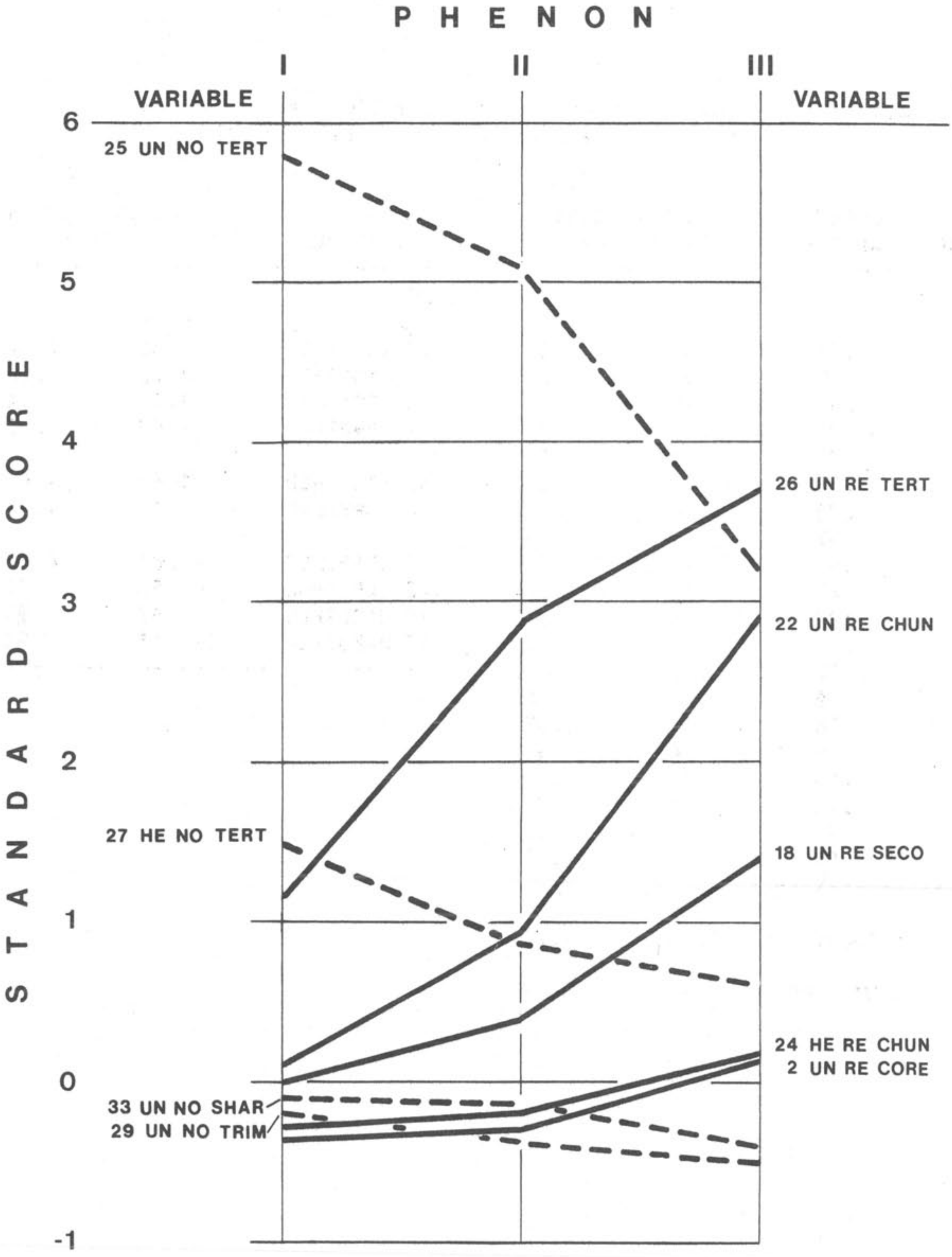

Figure 4.11. Intergroup variation of 9 artifact classes on 3 phenons defined on the basis of artifact class patterning (n = 12 sites).

Table 4.5. Principal Components Analysis (Q-Mode) of 20 Cases on 44 Artifact Class and 4 Size Grade Variables.

CASE	COMMUN-ALITIES	SORTED ROTATED FACTOR LOADINGS	
		1	2
G	.98	.93	.34
N	.89	.92	.23
P	.96	.91	.37
A	.97	.85	.49
R	.98	.84	.52
J	.98	.81	.56
H	.98	.79	.60
O	.97	.79	.59
B	.96	.78	.60
Q	.87	.74	.57
M	.98	.74	.66
F	.97	.73	.66
L	.98	.73	.67
I	.96	.70	.68
D	.96	.34	.92
E	.88	.24	.91
T	.95	.46	.86
S	.96	.54	.81
C	.95	.58	.78
K	.87	.58	.73
	EIGENVALUE	17.76	1.25
	CUM. PROP.	.89	.95

VARIABLE	FACTOR SCORES (>.75 o)	
	1	2
47 QUARINCH	4.56	0.00
25 UNNOTERT	3.70	.20
48 LESSQUAR	1.11	- .74
27 HENOTERT	1.02	- .53
46 HALFINCH	1.67	4.07
26 UNRETERT	.62	1.08
45 ONEEINCH	-1.81	4.57
22 UNRECHUN	- .54	1.11
18 UNRESECO	- .67	.99
17 UNNOSECO	- .47	.92

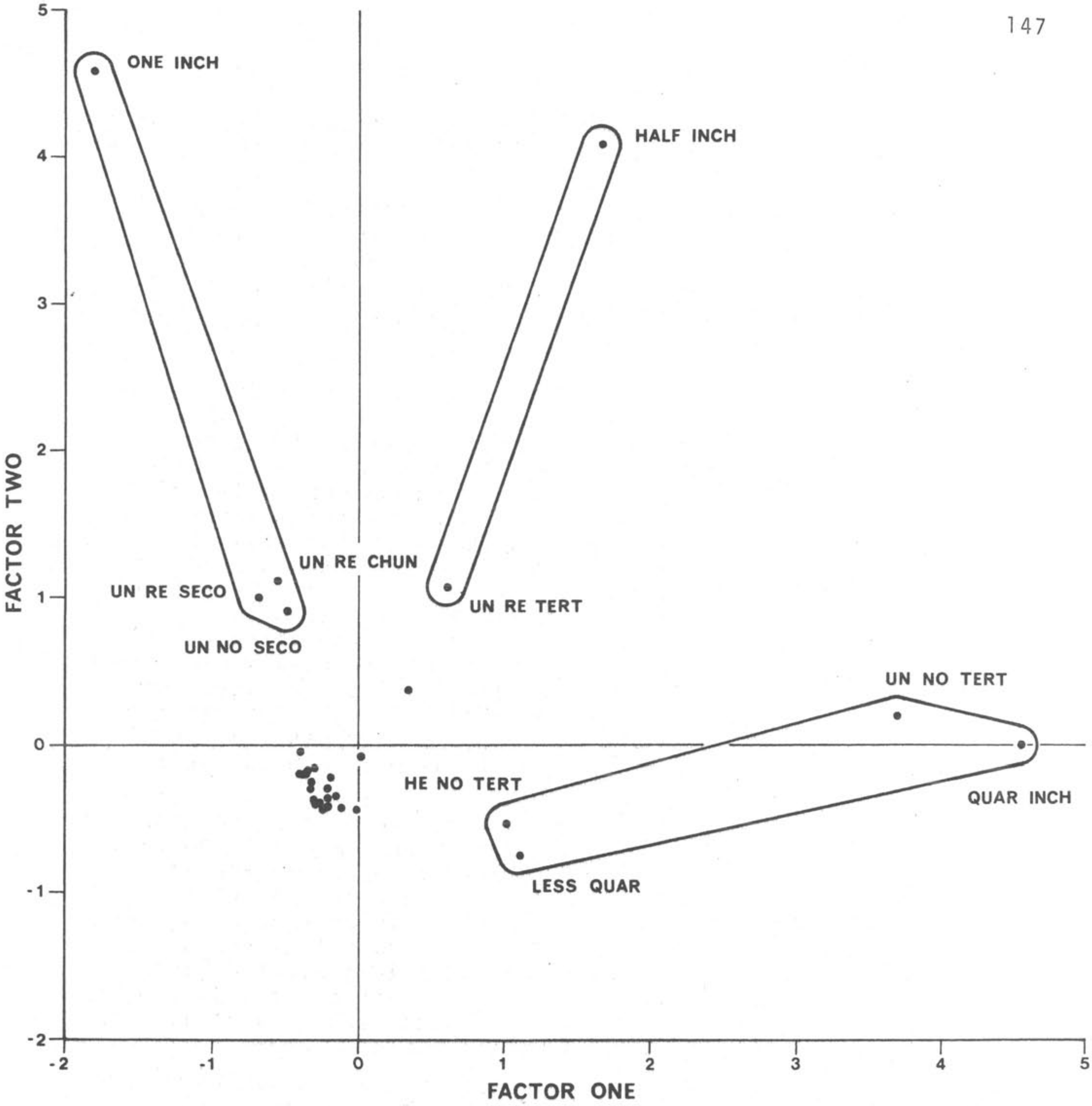

Figure 4.12. Plot of factor scores generated from principal components analysis (Q-mode) of 20 sites using 4 size grade variables and 44 artifact class variables.

sions of time, space, and site magnitude to determine whether nontechnological variables are associated with these configurations and trends.

Three stepwise discriminant function analyses were conducted, using the 35 context and magnitude variables presented in Table 4.4 to discriminate between groups of technologically similar sites. Groups are comprised of phenons derived from the three cluster analyses presented above, including five size grade phenons (Fig. 4.7), three artifact class phenons (Fig. 4.8), and seven size-class phenons (Fig. 4.9).

Results of the three discriminant analyses indicate that our set of context and magnitude variables is not capable of forming strong functions which discriminate well between technological phenons as they are currently defined. In the most successful attempt (size grade phenons) only nine of twenty cases (45%) were correctly classified by a jackknife classification procedure (wherein each case is classified into a group based on classification functions computed from all data *except* that contained in the case being classified). Further, *only* four of the 35 variables were sufficiently powerful to be entered into the function (F-to-enter = 4.0). Nevertheless, the identities of three of these variables are of great interest; they include mean artifact density, maximum artifact density, and sample size. All are indicators of site magnitude, a dimension which, on the basis of the settlement model, can be expected to associate with varying site functions.

To evaluate the significance of these implied relationships, rank-orders of site magnitude values were compared with rank-orders of site coordinates (derived from one-dimensional NMMDS solutions) using the Spearman rank-order correlation coefficient. Results indicate that significant correlations exist between the three density-related magnitude variables and site sequences generated from the size grade and size-class data sets (Table 4.6). The strongest correlations occur on the mean density variable, while site size is virtually uncorrelated with any of the site sequences.

Plots of the mean density and site size variables on the size-class sequence illustrate representative trends (Fig. 4.13) and also point out an interesting hiatus on the mean density regression, between sites B and F. Inspection of companion plots (not presented here) indicates that gaps occur consistently on regressions of the three density-related variables; most can be qualified as dumbbell-shaped configurations. Although compositions of the end clusters vary somewhat from plot to plot, the fact that groupings do occur implies that artifact density, in concert with technological factors, is a useful indicator of site types. Further, shapes of the dumbbell regressions suggest that a simple dichotomy of types is present in Putman Bottom.

Table 4.6. Spearman Rank-Order Correlations of Four Surface Magnitude Variables on Size Grade and Artifact Class Variables Arranged by 1-Dimensional Non-Metric Multidimensional Scaling Solutions.

	MEAN DENSITY		MAXIMUM DENSITY		SAMPLE SIZE		SITE SIZE	
	r_s	p	r_s	p	r_s	p	r_s	p
SIZE GRADE (n = 20)	-.83	<.01	-.79	<.01	-.68	<.01	-.22	>.20
SIZE + CLASS (n = 20)	-.79	<.01	-.71	<.01	-.62	<.01	-.18	>.40
ARTIFACT CLASS (n = 12)	-.43	>.10	-.36	>.20	-.36	>.20	-.10	>.50

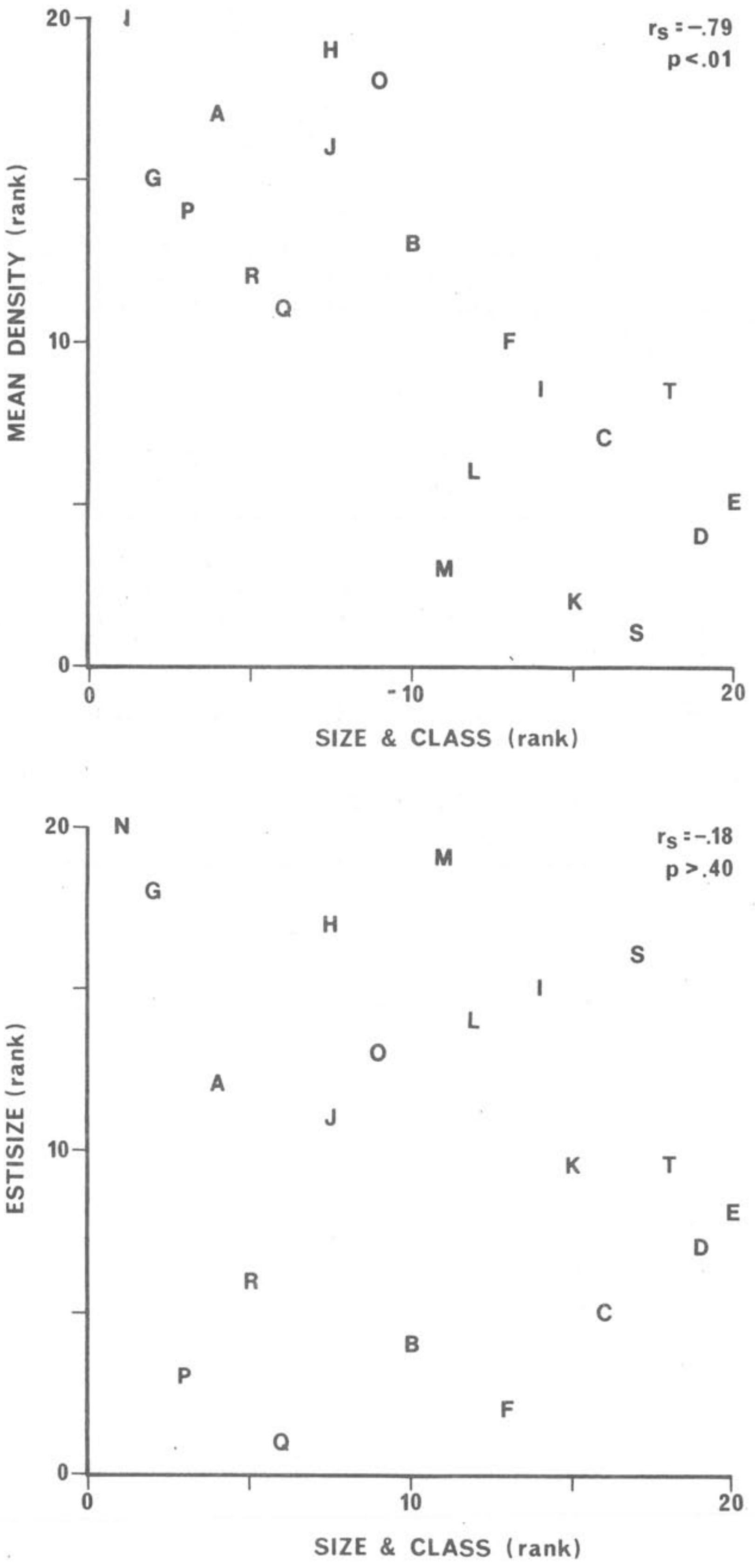

Figure 4.13. Rank-order regressions of mean density and site size on a one-dimensional non-metric multidimensional scaling configuration of intersite relationships defined on the basis of size grade and artifact class patterning (n = 20; stress = .18).

DISCUSSION

Analysis of technological factors and density functions indicates that variability is significant and patterned among sites in the Putman Bottom locality and has a fairly simple structure. Consolidated interrelationships among size grade variables, artifact class variables, and measures of surface artifact density form a general continuum which ranges from:

1. relatively dense sites, with surface aggregates dominated by small artifacts which hypothetically reflect processes of tool manufacture and tool maintenance (unretouched tertiary flakes, sharpening flakes, and trimming flakes); to:
2. relatively sparse sites, with surface aggregates dominated by large artifacts which hypothetically reflect processes of tool use (retouched tertiary flakes, chunks, secondary decortification flakes, and cores; and nonretouched secondary flakes).

Beyond this, applications of site magnitude functions to the various technological continua indicate the Putman sites can be sorted into two major groups, each of which is hypothetically suggestive of distinct sets of systemic functions. These include:

1. residential sites with high artifact densities indicative of intensive and/or recurrent occupations, and assemblages which represent light domestic activities; and
2. procurement/processing sites with low artifact densities indicative of infrequent and/or temporary utilization, and assemblages which represent resource extraction and/or heavy processing activities.

A variety of implications can be derived from this hypothesis, several of which are testable with available data: (1) site type variability should occur within temporal periods; (2) locational criteria for residential and procurement/processing sites should differ; (3) residential sites should contain subsurface evidence of domestic activities; and (4) residential sites should contain evidence of recurrent occupation. Each of these implications is briefly discussed in the following sections.

Time

If the hypothesized site types represent systemic variation of activities, both types should be represented within specific temporal periods. In the Putman sample, artifacts diagnostic of the Late Woodland period are relatively common (Table 4.4). Assuming these artifacts are valid indicators of site use in time, we find that Late Woodland period components occur in all size grade phenons (5/5), in all artifact class phenons

(3/3), in most size-class phenons (5/7), and in both hypothesized site types. Thus, sites utilized during the Late Woodland period were technologically diverse, and we conclude that this finding is consistent with a systemic explanation of differences between site types.

Space

If the hypothesized site types are differentiated by habitational vs. extractive activities, locational constraints and site contexts should differ. Residential sites can be expected to have recurrent contextual characteristics reflective of day-to-day domestic requirements, while locations of procurement/processing sites should be less structured, assuming they reflect extensive exploitation of dispersed bottomland resources. A map of dichotomized Putman sites (Fig. 4.14) suggests these expectations are generally true. Most hypothesized residential sites occur on level to gently sloping surfaces near outer terrace margins, overlooking temporary or permanent water sources. Procurement/processing sites occupy less consistent contexts; many occur between the parallel configurations of residential sites, often on sloping land with less direct access to water sources. Thus, we conclude that observed site contexts are consistent with locational implications derived from inferred site functions.

Subsurface Associations

If the hypothesized residential sites represent relatively long term loci of domestic activities, we expect that odds favoring the occurrence of subsurface domestic features are greater among residential sites than among short term procurement/processing sites. To test this implication, plowzone deposits were removed by heavy machinery from five residential sites (A, G, H, N, O) and two procurement/processing sites (E, I). Features were discovered only at sites N and O, both of which are hypothesized residential sites perched on high terrace margins. Although feature shapes and contents have not yet been analyzed in detail, most appear to represent facilities for storage and/or refuse disposal. Thus, results are consistent with expectations. However, reasons for the absence of features at sites A, G, and H are unclear. If the three did function as residential sites, they may represent seasonal encampments on lowlying flood plains in which subsurface facilities were not utilized.

Recurrent Occupation

If, as has been suggested, locational contexts of residential sites are conducive to habitation, and if locational

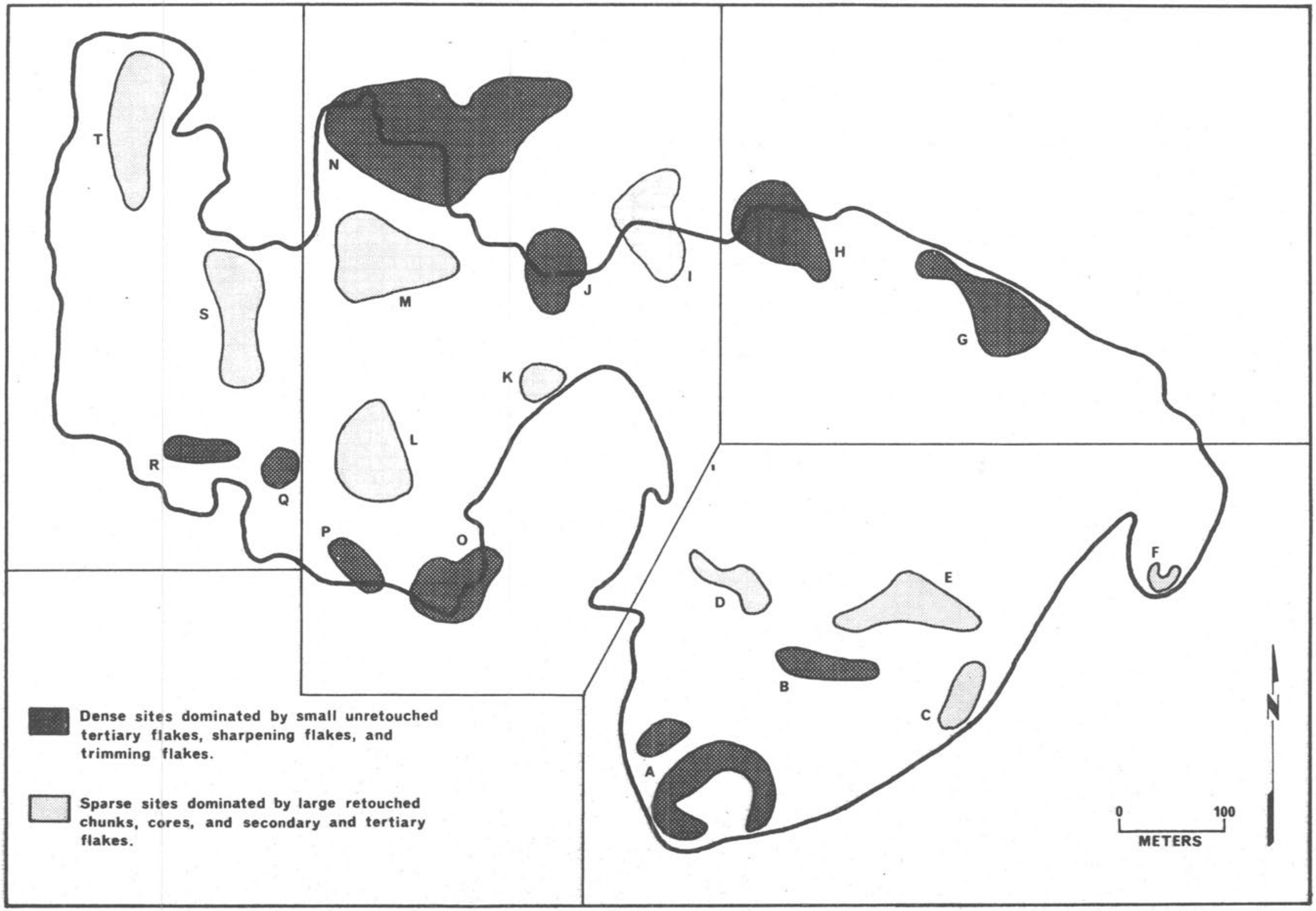

Figure 4.14. Locations of sites dichotomized on the basis of artifact class patterning, size grade patterning, and mean surface artifact density.

requirements for residential sites did not vary greatly through time, then cultural-temporal indicators from hypothesized residential sites should demonstrate long term recurrence of occupations (i.e., multiple components). To test this proposition, the components variable in Table 4.4 was used to dichotomize multicomponent vs. single component sites, and results were compared with the site type dichotomy. Fisher's Exact Test was used to determine whether observed frequencies (six residential-multiple; four residential-single; zero procurement-multiple; 10 procurement-single) are too rare to have occurred by chance alone. A value of $\underline{p} = .005$ was obtained, which is statistically significant at alpha = .01. Thus, we conclude that hypothesized residential sites were used more recurrently through time than chance would allow, a finding which offers indirect (and admittedly weak) support for the hypothesis.

CONCLUSIONS

Relationships among sites in the Putman Bottom locality, when viewed from the perspective of technological patterning, are best represented by a unidimensional configuration of cases. Importantly, proportions of associated technological classes vary systematically along this dimension. Several surface magnitude factors also correlate with the configuration, and indicate that sites in the sequence can be segregated into two general groups. Characteristics of these groups, such as proportional associations of related artifact classes, proportions of artifact size grades, and surface artifact densities, suggest the two groups represent a dichotomy of distinctive sets of functions which are related to patterns of settlement and resource extraction. Four tests of this induced hypothesis offer consistent support. Although additional research (currently underway) is needed to identify the specific functions represented within and among groups, available data indicate strongly that diversity among sites in the Putman locality is directly related to variation in function. Therefore, we conclude that our findings are consistent with O'Brien and Warren's (1979) expectations (deduced from ecological theory) that functional diversity is high among sites in Prairie Peninsula bottomlands containing varied and dispersed natural resources, and settlement locations in narrow banded environments are conditioned more by domestic requirements than by strategic resource needs.

Additionally, we believe our results reflect favorably on surface collected artifacts as a useful source of data for testing models of prehistoric behavior. Variability among Putman sites is statistically significant, and is also meaningful from an interpretive standpoint. Although relationships have probably been smoothed by depositional and post-depositional processes, general trends stand out clearly and have provided valuable insights into prehistoric bottomland activities.

ACKNOWLEDGMENTS

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STATISTICAL APPROACHES TO SHALLOW SITE ARCHEOLOGY: ANALYSIS OF THE O'NEAL SITE, JEFFERSON COUNTY, ALABAMA

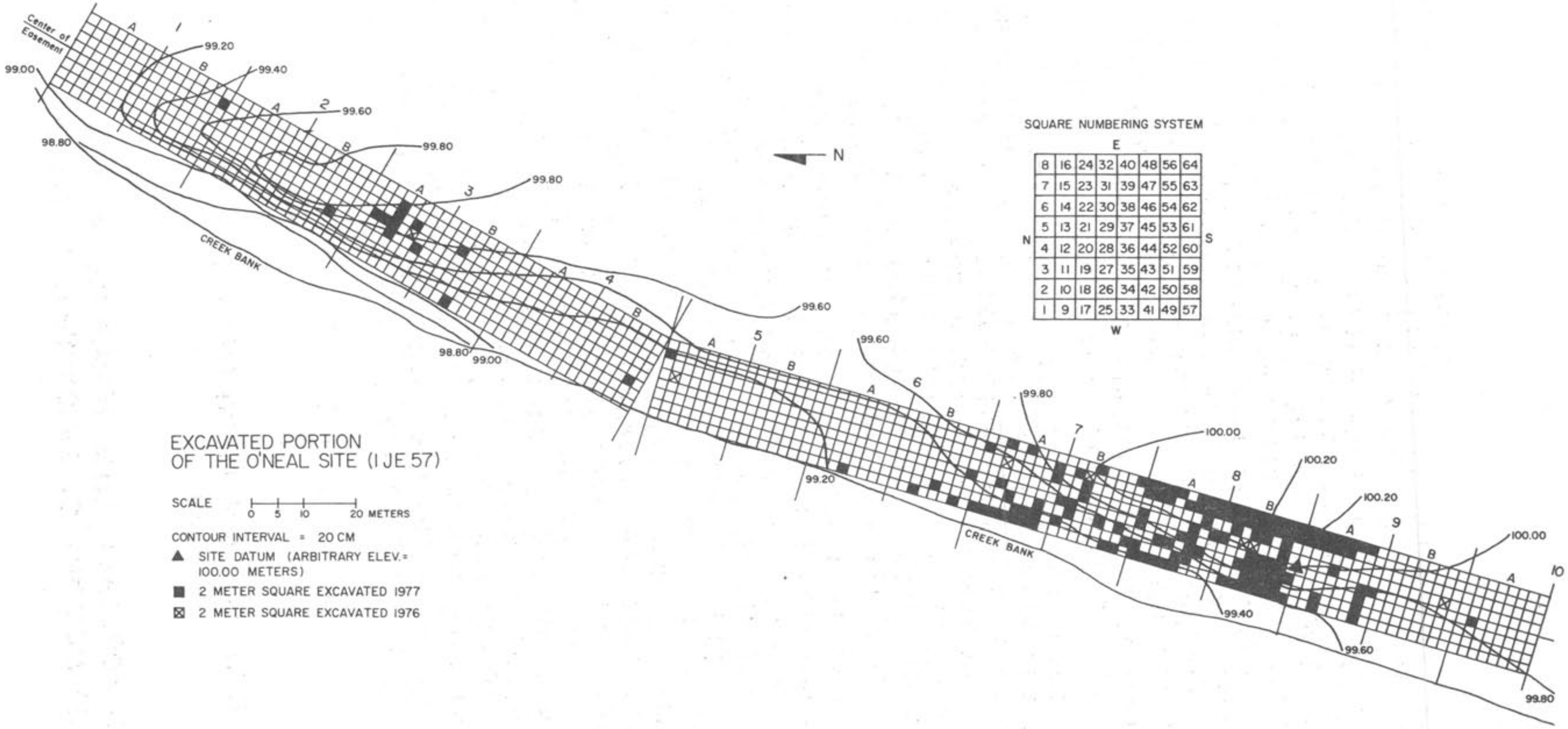
by
C. Roger Nance and David C. Hurst

INTRODUCTION

Detailed surface collection studies (Redman and Watson 1970; Binford et al. 1970) and recent excavations at the Zebree site (Morse 1976) have established the potential of horizontal analysis of shallow, intensively occupied sites, even though disturbed through plowing. This paper considers analysis of a different type of shallow, plowed site, one occupied lightly and producing small quantities of cultural debris. The technique developed for this analysis involves attribute analysis of excavated debitage, stone tools, and prehistoric pottery. Vertical trends in flake attributes, viewed level by level with all square data combined, were used to identify time-sensitive flake variables. These in turn were utilized to set the squares in relative sequence, with the flake data viewed by square, all levels combined. Artifact attribute changes through time were then identified using this square sequence, as will be explained below.

The O'Neal site is located on the flood plain of a tributary of Locust Fork of the Warrior River in north-central Alabama. During field work, carried out in a sewerline construction salvage project, 143 two-meter-square units were excavated, situated along 300 meters of the pipeline easement (Fig. 5.1). Over 18,000 flakes and spalls, 624 bifaces, 175 other lithic tools, and 240 sherds were excavated.

Following initial test excavations, the research aim became one of isolating and sampling different occupations at different (horizontal) localities on the site. Two-meter-square excavation units were selected both randomly (81 squares) and non-randomly (62 squares) within the grid established on the easement. Random squares were chosen using a stratified technique, with squares selected randomly from 128 and 64 square blocks (Fig. 5.1). Details of the square selection process are described in Nance and Hurst (1978). All deposits excavated were dry screened through 1/4" hardware cloth. For each square, the plowzone (about 30 cm thick) was carefully removed stratigraphically, while underlying deposits were excavated in 10 cm levels.



8	16	24	32	40	48	56	64
7	15	23	31	39	47	55	63
6	14	22	30	38	46	54	62
5	13	21	29	37	45	53	61
4	12	20	28	36	44	52	60
3	11	19	27	35	43	51	59
2	10	18	26	34	42	50	58
1	9	17	25	33	41	49	57

Figure 5.1. Excavated portion of the O'Neal site, 1JE57.

FLAKE ANALYSIS

Several assumptions guided formulation of the study of lithic flakes:

(1) horizontal and/or vertical distributional patterns of flake attributes might be discovered on the site (even though the site is shallow with most cultural debris confined to the plow zone);

(2) the patterns, if discovered, would represent different episodes or periods of chipped stone tool manufacturing; and

(3) these patterns would reflect differences in flaking technology, effects of differences in parent stone material, manufacture of different forms of stone tools, or more than one of these potentially interrelated variables.

Generally, attributes were selected on the basis of prior use in descriptive flake studies and on the basis of ease and consistency in measurement. Provenience for each flake studied was recorded by square and level or feature. Fourteen material classes were recorded according to the lithological categories established by a minerologist (Nielson 1978). Flake morphology was described using the criteria of blade (flakes with lengths at least twice their widths) vs. flake, cortex surface (present or absent), and bifacial thinning flake vs. other type of flake. Bifacial thinning flakes are defined as flakes with remnants of both biface surfaces on the striking platform extremity. Using these criteria, six morphological classes are defined: blade with cortex; blade without cortex; blade with bifacial thinning; flake with cortex; flake without cortex; and flake with bifacial thinning. Spall morphology was recorded for non-flake pieces of detritus too fragmentary to be considered cores (lacking complete flake scars). Three spall morphological classes were utilized: spall with river pebble cortex; spall without cortex; and spall, with non-river pebble cortex (with an angular, weathered surface). Flake completeness is a somewhat misleading title. Actually, this attribute separates obviously complete flakes (those which taper to an edge opposite a striking platform) from all others, including whole flakes which terminate with step fractures. Maximum dimensions were recorded to the millimeter. Finally, used flakes were distinguished from non-used flakes.

Flakes studied were selected randomly by square through a stratified procedure described in Nance and Hurst (1978). Approximately 6,000 flakes and spalls from 42 of the 143 excavated units were analyzed.

Distributional Data

Flake Distribution by Size

Flakes were broken down into five size grades (0.6-1.1, 1.2-1.3, 1.4-1.6, 1.7-2.0, and 2.1-6.4 cm) and were tabulated by excavation levels, all squares combined (Table 5.1). Chi-square analysis indicates that small flakes occur more frequently than expected in lower excavation levels and large flakes occur more frequently in upper levels ($p = .001$).

Flake size also varies horizontally over the site, and was found to covary with the number of flakes in each square. Small flake (0.6 - 1.1 cm) percentages (percentages of flakes totaled by square) vary directly with flake frequencies by square, while large flake (2.1 - 6.4 cm) percentages vary inversely. Correlation coefficients are $r = .5666$ and $r = -.5118$ respectively, both significant at $p = .001$.

Flake Distribution by Morphology

Table 5.2 depicts the distribution of flakes by level and morphological class. Cortex flake percentages increase significantly from lower to upper levels, while the reverse is true for flakes without cortex. By square, cortex flake percentages vary inversely with square flake frequencies ($r = -.4677$; $p = .01$); non-cortex flakes vary directly.

Flake Size and Morphological Classes Compared

Given the trends described above, it is not surprising to find that attributes of size and morphology covary with one another; cortex flakes are significantly larger than non-cortex flakes.

When horizontal distributions of size and morphological class percentages are contrasted, definite patterns emerge. Figure 5.2 compares a division of flake-study squares on the basis of above and below average percentages (by square, levels combined) of large flakes to a division on the basis of above and below average percentages of cortex flakes. While squares with above average counts of both cortex and large flakes are spread widely over the site area investigated, squares with below average counts for both variables tend to concentrate in the eastern part of block 8 B. Also, squares with high counts (above average) of cortex flakes but low in large flakes tend to cluster in the eastern portions of blocks 8 A and 8 B; squares high in large flakes but low in cortex flakes cluster in the centers of blocks 8 A and 8 B.

Flake Material Distributions

Materials also show what apparently are non-random vertical trends (Table 5.3). Banded chert, brown chert,

Table 5.1. All Flakes by Dimensions and Level, All Level Sample.

DIMENSION

FREQUENCY EXPECTED COL PCT	LEVEL							
	ONE	TWO	THREE	FOUR	FIVE	SIX	OTHER	TOTAL
0.6--1.1	669 829.9 16.30	253 201.6 25.38	134 94.2 28.76	74 40.2 37.19	26 11.3 46.43	23 7.5 62.16	19 13.3 28.79	1198 20.22
1.2--1.3	783 802.2 19.07	216 194.8 21.66	102 91.1 21.89	31 38.9 15.58	9 10.9 16.07	3 7.2 8.11	14 12.9 21.21	1158 19.54
1.4--1.6	1011 974.0 24.63	222 236.5 22.27	90 110.6 19.31	44 47.2 22.11	15 13.3 26.79	6 8.8 16.22	18 15.7 27.27	1406 23.73
1.7--2.0	849 795.2 20.68	162 193.1 16.25	88 90.3 18.88	33 38.6 16.58	3 10.8 5.36	4 7.2 10.81	9 12.8 13.64	1148 19.37
2.1--6.4	793 703.8 19.32	144 170.9 14.44	52 79.9 11.16	17 34.1 8.54	3 9.6 5.36	1 6.3 2.70	6 11.3 9.09	1016 17.14
TOTAL	4105 69.27	997 16.82	466 7.86	199 3.36	56 0.94	37 0.62	66 1.11	5926 100.00

Chi-Square = 222.619 with 24 D.F., Prob. of Greater Value under H_0 = 0.0001

Table 5.2. All Flakes By Morphology And Level, All Level Sample.

MORPHOLOGY

FREQUENCY EXPECTED COL PCT	LEVEL ONE	 TWO	 THREE	 FOUR	 FIVE	 SIX	 OTHER	 TOTAL
BLADE_BI	0 0.7 0.00	0 0.2 0.00	0 0.1 0.00	0.0 0.0 0.00	0 0.0 0.00	0 0.0 0.00	1 0.0 1.52	1 0.02
BLADE_CO	22 18.0 0.54	3 4.4 0.30	1 2.0 0.21	0 0.9 0.00	0 0.2 0.00	0 0.2 0.00	0 0.3 0.00	26 0.44
BLADE_NC	109 115.7 2.66	31 28.1 3.11	16 13.1 3.43	6 5.6 3.02	2 1.6 3.57	1 1.0 2.70	2 1.9 3.03	167 2.82
FLAKE_BI	88 81.7 2.14	19 19.9 1.91	7 9.3 1.50	2 4.0 1.01	1 1.1 1.79	1 0.7 2.70	0 1.3 0.00	118 1.99
FLAKE_CO	489 457.9 11.91	115 111.2 11.53	42 52.0 9.01	9 22.2 4.52	1 6.2 1.79	0 4.1 0.00	5 7.4 7.58	661 11.15
FLAKE_NC	3397 3431.0 82.75	829 833.3 83.15	400 389.5 85.84	182 166.3 91.46	52 46.8 92.86	35 30.9 94.59	58 55.2 87.88	4953 83.58
TOTAL	4105 69.27	997 16.82	466 7.86	199 3.36	56 0.94	37 0.62	66 1.11	5926 100.00

Chi-Square = 121.817 with 30 D.F., Prob of Greater Value under H_0 = 0.0001

Table 5.3. All Flakes By Material And Level, All Level Sample.

MATERIAL

FREQUENCY EXPECTED COL PCT	LEVEL							
	ONE	TWO	THREE	FOUR	FIVE	SIX	OTHER	TOTAL
BANDED CHERT	168	32	16	2	0	1	4	223
	154.5	37.5	17.5	7.5	2.1	1.4	2.5	3.76
	4.09	3.21	3.43	1.01	0.00	2.70	6.06	
BLACK FLINT	4	3	0	0	0	0	0	7
	4.8	1.2	0.6	0.2	0.1	0.0	0.1	0.12
	0.10	0.30	0.00	0.00	0.00	0.00	0.00	
BROWN CHERT	107	15	5	2	2	0	2	133
	92.1	22.4	10.5	4.5	1.3	0.8	1.5	2.24
	2.61	1.50	1.07	1.01	3.57	0.00	3.03	
CHERT SANDSTONE	733	189	63	38	18	11	9	1061
	735.0	178.5	83.4	35.6	10.0	6.6	11.8	17.90
	17.86	18.96	13.52	19.10	32.14	29.73	13.64	
CHERT SILTSTONE	72	17	2	4	0	1	1	97
	67.2	16.3	7.6	3.3	0.9	0.6	1.1	1.64
	1.75	1.71	0.43	2.01	0.00	2.70	1.52	
FLINT SANDSTONE	96	19	11	8	1	0	3	138
	95.6	23.2	10.9	4.6	1.3	0.9	1.5	2.33
	2.34	1.91	2.36	4.02	1.79	0.00	4.55	
FLINT	552	121	38	18	5	3	10	747
	517.5	125.7	58.7	25.1	7.1	4.7	8.3	12.61
	13.45	12.14	8.15	9.05	8.93	8.11	15.15	
JASPER	332	56	27	10	1	0	5	431
	398.6	72.5	33.9	14.5	4.1	2.7	4.8	7.27
	8.09	5.62	5.79	5.03	1.79	0.00	7.58	
MOTTLED CHERT	89	21	6	2	0	0	0	118
	81.7	19.9	9.3	4.0	1.1	0.7	1.3	1.99
	2.17	2.11	1.29	1.01	0.00	0.00	0.00	
QUARTZ SANDSTONE	194	64	29	6	1	0	5	299
	207.1	50.3	23.5	10.0	2.8	1.9	3.3	5.05
	4.73	6.42	6.22	3.02	1.79	0.00	7.58	
QUARTZITE	8	2	1	0	0	0	0	11
	7.6	1.9	0.9	0.4	0.1	0.1	0.1	0.19
	0.19	0.20	0.21	0.00	0.00	0.00	0.00	
SILICEOUS SANDSTONE	154	34	15	5	3	0	4	215
	148.9	36.2	16.9	7.2	2.0	1.3	2.4	3.63
	3.75	3.41	3.22	2.51	5.36	0.00	6.06	
VEIN QUARTZ	29	7	2	0	0	0	0	38
	26.3	6.4	3.0	1.3	0.4	0.2	0.4	0.64
	0.71	0.70	0.43	0.00	0.00	0.00	0.00	
WHITE CHERT	1567	417	251	104	25	21	23	2408
	1668.0	405.1	189.4	80.9	22.8	15.0	26.8	40.63
	38.17	41.83	53.86	52.26	44.64	56.76	34.85	
TOTAL	4105	997	466	199	56	37	66	5926
	69.27	16.82	7.86	3.36	0.94	0.62	1.11	100.00

Chi-Square = 140.876 with 78 D.F., Prob of Greater Value Under H_0 = 0.0001 flint, jasper and mottled chert generally increase in relative frequency from lower to upper levels, while white chert shows an opposite trend (significant at the p = .0001 level).

As for certain size and morphological attribute classes, several materials were found to correlate with flake frequencies. White chert flake percentages by square vary directly with flake frequencies (r = .5438; p = .0001), while percentages for jasper vary inversely (r = -.4819; p = .01).

Flake Material, Size, and Morphological Attributes Compared

Given vertical trends in some material classes as well as in morphological and size classes, it is possible to predict patterns of covariation among size and material, and morphological and material attribute classes. For the data to be fully consistent, more white chert flakes should be in the smallest size class (0.6 - 1.1 cm) than expected through random distribution. Conversely, less than expected banded chert, brown chert, flint, jasper and mottled chert flakes should be in the same class. Similar covariation can be predicted for materials and morphological classes, with white chert hypothetically manifesting relatively low cortex flake frequencies, while the other above mentioned materials should show an opposite tendency. Actual distributions generally conform to these predictions.

Horizontal covariation among all three attributes is suggested by the data. Material classes which show vertical trends were compared for squares with above average percentages of both large flakes and cortex flakes, as opposed to squares with below average percentages of both large flakes and cortex flakes (see Fig. 5.2). The chi-square value is significant at the p = .0001 level. Moreover, results are predictable in that horizontal distributions reflect vertical trends described above; large flakes and cortex flakes are more frequent in upper levels. Horizontally, these attribute classes associate strongly with material classes which also are more frequent in upper levels (banded chert, brown chert, flint, jasper, and mottled chert). Conversely, white chert flakes which increase proportionately with depth are most dominant in squares low in cortex and large flakes.

Used Flakes

The above flake data include all flakes studied, both used and non-used. In addition, for levels 1 and 2 (excluding flakes from lower levels), used and non-used flakes were analyzed separately. In comparing used and non-used flake tables, statistically significant differences were found between the two groups in the matter of flake size: used flakes fall more frequently than expected into large flake categories.

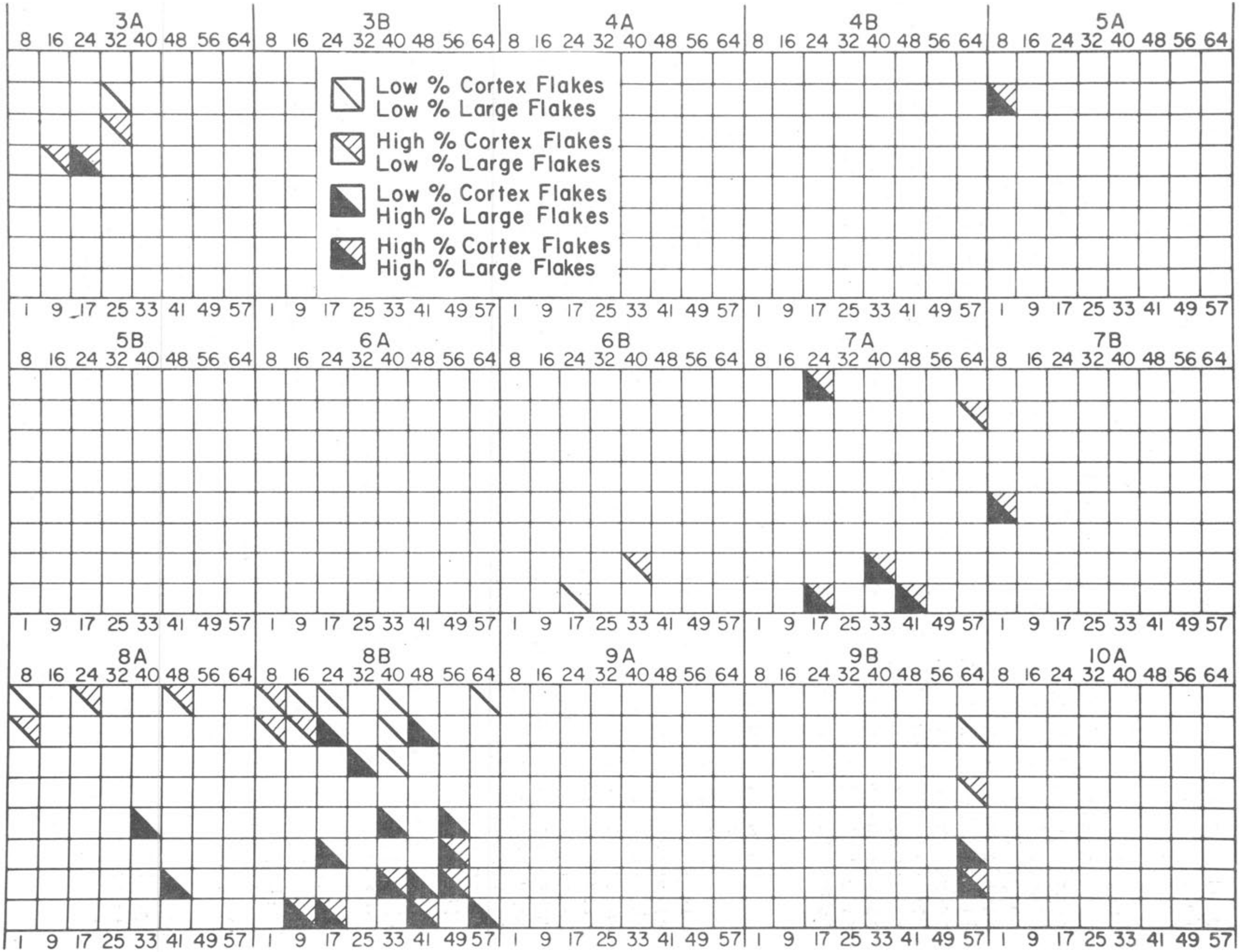


Figure 5.2. Selected flake attribute percentages, 42 flake study squares.

Also, non-used flakes show a shift in size by level, with higher proportions of small flakes in level 2 than 1. This duplicates the trend found for all flakes through all levels. In contrast, used flake size class proportions do not vary significantly between levels 1 and 2.

Spalls

Spall distributions were studied through reference to contingency tables, similar to those generated for flakes (comparing the variables of provenience, material, size, and morphology). Only 244 spalls were included in the study sample and in many cases the utility of spall tables was limited by insufficient data. In several tables, however, trends which parallel those encountered for flakes are apparent. For example, small spalls increase proportionately from upper to lower levels, repeating the trend for small flakes, and spalls with and without cortex vary with vertically trending material classes (established for flakes) in the same manner found for flakes with and without cortex.

Summary and Interpretation of Flake Distributional Data

Altogether, flake data from the O'Neal site present a consistent pattern. Vertical distributional differences in flake materials, morphology, and size are repeated horizontally, when the data are viewed on a square by square basis. Specifically, white chert occurs predominately in lower levels where small flakes and non-cortex flakes are relatively frequent. Banded chert, brown chert, flint, mottled chert, and jasper become more prevalent in upper levels, where flakes of these materials tend to be large and more often exhibit cortex surfaces than do flakes from lower levels. The same size-morphology-material clusters are discerned horizontally in different areas of the site.

Trends in the flake data described above could be a result of multifarious causes, most probably related to one of the factors mentioned above, including:

(1) differing flaking characteristics of stone materials being worked;

(2) representation on the site of different prehistoric lithic technologies; and

(3) differences produced by the manufacture of different types of chipped stone tools.

A fourth factor which may have produced the patterning, at least in the production of vertical trends, is mixing. Specifically, vertical trends by size may be due to the mechanics of mixing, with possibly small flakes tending to percolate downward more than large ones. Two hypotheses dealing with this problem were formulated:

Mixing Hypothesis

Here, basic vertical trends in the flake attribute data are considered to be the result of mixing. It is also proposed that different materials produced different flake patterns (in terms of size and morphology) because of the different forms in which each was obtained by the aboriginal flint knappers. If material such as flint was available only as stream pebbles, one might expect more cortex flakes produced from that material. Also, white chert might have occurred primarily in bedrock outcroppings, thus explaining a low proportion of cortex flakes for that material. Differences in flake size by material also could be due to relative amounts of different lithic materials available, and possibly due to selective use of some materials for certain artifact forms.

Given production of these unique flake patterns for different materials, horizontal patterns described above can be simply explained as being due to flaking of different materials on different parts of the site. If this is the case, and if churning of the deposits did cause small flakes to settle below large flakes, vertical trends in size, morphology and material class could all be due to mixing. For example, if small flakes percolated downward, white chert flakes, which are generally small, would tend to become more plentiful in lower layers. Cortex flakes, generally larger, would occur in higher proportions in upper levels.

Culture Change Hypothesis

Here, culture change is seen as the primary cause of vertical trends. Earlier occupations produced more finished artifacts and left smaller flakes and more non-cortex flakes in lower levels. Earlier occupants also used more white chert. This would explain why white chert flakes are generally small, and why relatively few white chert flakes have cortex surface. Later occupations produced fewer finished artifacts on the site, explaining higher percentages of large and cortex flakes in upper levels and why materials more prevalent in upper levels tend to be most represented by cortex and large flakes. Horizontal distributions reflect the locations of early and late occupations on the site.

Discussion

It is possible to critically examine the two hypotheses on the basis of internal data from the O'Neal site.

There are two findings which mitigate against the mixing hypothesis. In the first place, used flakes are larger than non-used flakes, and therefore one would expect used flake proportions to decrease from upper to lower levels if mixing occurred. Analysis of used and non-used flakes from levels 1 and 2 indicates no significant difference in used flake proportions (Nance and Hurst 1978: Table 3.35). Also, used flakes do not show any size shift between levels 1 and 2, as do non-used flakes. In terms of culture change it is plausible that different cultures would continue to select the same-sized flakes for utilization while over-all patterns of chipped stone artifact production changed. At the same time, it is difficult to reconcile these data to the mixing hypothesis.

Along the same lines, all flakes were recorded as being whole (with striking platform, and opposing end tapering to an edge) as opposed to all others. Complete flakes, as expected, are larger than fragments, but it is the vertical distribution which is of interest. There are no significant differences in proportions of whole vs. fragmented flakes through the upper three levels, which contain ca. 94% of the studied sample. Mixing, if operating as hypothesized, should have increased the percentages of fragments in levels 2 and 3 over that for level 1. We must add, however, that data below level 3 do support the mixing hypothesis, as larger than expected proportions of flake fragments are present.

The data, then, are not entirely consistent with the mixing hypothesis. Remaining to be examined is the alternative, culture change. One way to test this hypothesis is to turn to formed lithic artifacts. If vertical changes in the artifact types or attributes can be found which are technologically compatible with the changing flake populations by level, the hypothesis would be supported. The same can be said for horizontal flake patterns and possible artifact type or attribute covariation. Finally, ceramic attribute distributions provide another possible test of the culture change hypothesis. Ceramic and flake attribute distributional covariation would clearly indicate a sequence of occupations on the site.

The evidence for lithic artifact attribute and ceramic attribute covariation with this flake data is discussed below.

LITHIC ARTIFACT DISTRIBUTIONAL ANALYSIS

Because flake trends were so consistent, it was decided to accept culture change as a working hypothesis and to use horizontal flake distributions to structure a horizontal study of artifacts. A second assumption was that different horizontal flake patterns represent different occupations. A third assumption was that artifacts and flakes from the same occupation occurred in the same squares.

The strategy employed was to use the flake data to build a chronology for squares included in the flake study on a square by square basis. That is, flake samples from each square (all levels combined) were placed into its chronological position relative to other square flake samples.

Square percentages were tabulated for attribute classes which most showed a tendency to shift percentage-wise, either increasing or decreasing from lower to upper levels. Classes selected were small flakes (0.6 - 1.1 cm), large flakes (2.1 - 6.4 cm), cortex flakes, white chert flakes, brown chert flakes, flint flakes, and jasper flakes.

The next step was to construct a new single variable which would provide a single dimension on which to scale age. For this, the Principal Component or Principal Axis factor technique (Morrison 1967) was selected. We used this technique because it produced the best fitting axis as well as the scale showing maximum variance, spreading factor scores to the greatest extent. Factor scores for the first, second, and third principal axes, a coefficient matrix of the variables, and coefficient matrix of the variables and factor scores for the three principal axes were computed.

Factor 1 correlates significantly with all variables, inversely with white chert and small flake, and directly with the others. Since small flake and white chert are "early" (low tending) variables and the others are "late", we can interpret a high positive factor score to indicate a recent occupation and a high negative score to indicate an early one.

At this point in the research, we encountered a problem with the data which interrupted our progress and led to a series of unforeseen analyses. In comparing factor scores to individual square data, it was found that squares with low (negative) factor scores tended to be those which were excavated most deeply. The problem was that squares in the flake study were grouped based on the number of levels dug, with factor scores averaged for each group. In general, the more levels excavated, the lower the average score.

One implication of this finding is that horizontal differences in flake distribution might not be real, that overall differences by square might only reflect proportions of flakes from lower levels included in the square samples, and not occupations located on different areas of the site. There is, however, another possibility. If, in fact, early and late occupations with different flake assemblages are represented across the site, horizontal flake patterns might have led us to excavate more levels in temporally earlier squares. During excavation, we excavated below level 2 in those squares which seemed to produce above average numbers of flakes and/or formed artifacts in level 2 (the first 10 cm level below the plowzone). While this is a traditional technique in field archeology, it is easy to see how this approach could have caused bias in the direction indicated. As described above, variables which hypothetically are time sensitive also correlate with flake frequencies by square. As can be anticipated, Factor 1 scores correlate closely with flake frequencies by square ($r = -.6931$; for 40 df, $p = .001$), with early squares (those with low factor scores) containing early levels tending to be those with high frequencies. It seems possible, then, that more lower levels were excavated in early squares because they contained more flakes.

In short, we faced a dilemma: more low levels had been dug in early squares or else "early" squares had been created by digging some (those with more flakes) to greater depths.

It was possible to circumvent this problem, although the procedure called for creation of another set of flake tables as well as another factor analysis (Nance and Hurst 1978: Tables 3.23-3.34). Levels 1 and 2 produced 86% of the total flakes studied. Since every square had been excavated at least two levels, we eliminated all material from below level 2, and thereby eliminated the problem caused by digging squares to different depths. In the process we lost part of the data's vertical dimension, limiting ourselves to differences between levels 1 and 2.

In a contingency table for level 1 and 2 flakes by level and material class (Nance and Hurst 1978: Table 5.3), the overall association is significant at $p = .05$, with several types of material exhibiting significant shifts in proportions. These are brown chert, jasper, quartz sandstone, and white chert; three of these four types of material also show similar trends when data from all levels are considered. The cortex flake variable does not shift significantly when only data from levels 1 and 2 are analyzed. The small (0.6 - 1.1 cm) and large (2.1 = 6.4 cm) flake variables do shift significantly, maintaining the trend established for all levels. Therefore, a second factor analysis was carried out, using data only from levels 1 and 2 for the following variables: brown chert, jasper, quartz sandstone, white chert, small flakes, and large flakes.

Square frequencies, variable percentages, and factor scores for this second factor analysis as well as the variable coefficient matrix, coefficient matrix of variables, and factor scores are presented in Nance and Hurst (1978). With this limited sample, correlations among variables and among variables and factors are not as strong. Nevertheless, there are parallels with the factor analysis for all flakes. Factor 1 for level 1 and 2 flakes correlates negatively with white chert (p = .05), and positively, though not significantly, with other materials. Generally, then, Factor 1 appears to measure age, with negative scores indicating early, and positive scores, more recent occupations. There are no correlations with flake size variables. Factor 2 scores, scaled on the second principal axis, contrast to those of Factor 1. There is significant correlation (p = .01) negatively with large flake percentages, and positively with small flake percentages, but there is very minor or no correlation with material variables.

An immediate use of the level 1 and 2 factor analysis was to evaluate the first factor analysis for all levels by establishing correlation between Factor 1 scores (all levels) and Factor 1 scores (levels 1 and 2). The correlation coefficient is high (r = .8308, for 40 df, p = .001), which indicates that general trends condensed into the initial factor analysis persist in the data, even after deleting flakes from levels below 2. This, in turn, renders unlikely the hypothesis that differential inclusion of lower level data produced the bulk of horizontal variation encompassed in the all level factor analysis. However, since some small portion of the horizontal variation might be due to the fact that only some squares contain flakes below level 2, the level 1 and 2 factor analysis and not the all-level analysis was used in subsequent stages of research.

The next step was to assign factor scores to squares not included in the flake study. It will be recalled that for the all-level analysis, Factor 1 scores correlated inversely with square flake frequencies. The same holds true for the Factor 1 scores of the level 1 and 2 analysis and flake frequencies for levels 1 and 2 (r = -.4808; for 40 df, p = .005). Factor 2, level 1 and 2 analysis, correlates directly with square flake frequencies (r = .5166; for 40 df, p = .001). Because flake frequencies had been tabulated by level for all squares during initial laboratory work, it was possible to estimate Factor 1 scores for each square not included in the flake study. This involved totaling level 1 and 2 flakes for each of these squares, and then subtracting 10.5 percent of the total from each. The latter step adjusted the raw or laboratory flake counts to approximate counts which would have resulted from intensive analysis (to account for spalls and non-flakes included in the original totals). Additional Factor 1 scores could now be estimated through use of a linear regression on the straight line of best fit (for the 42 square Factor 1 scores and 42 square flake frequencies); each additional score was based on an adjusted square flake frequency.

Furthermore, the same procedure, including a second linear regression was followed for Factor 2, taking advantage of the fact that Factor 2 scores also correlate closely with square flake frequencies. As noted above, Factor 1 is based primarily on material variables and Factor 2 on flake size variation. It seemed potentially advantageous to retain both indices for the study of artifacts and of artifact-flake covariation. It should be recognized, however, that since Factor 2 is the principal component remaining orthogonal to Factor 1, it must be expected to be often much less valuable than Factor 1.

At this point, we were in a position to see if the artifact data supported the hypothesis presented previously. If the different flake patterns, established both vertically and horizontally, are due to culture change and are the remains of different occupations, and if horizontally, artifacts and flake of the same occupations covary, then any vertical trends in artifact categories should be repeated horizontally, conforming to the horizontal (age) distributions of the flakes.

The research plan for lithic artifacts was first to identify vertical trends in artifact attributes, all squares combined, and then to assign a factor score to each artifact according to its square provenience. The relative age of any artifact class, form, or group could then be represented by the numerical average of the included artifact factor scores. Relative age determined vertically should match the relative age determined through averaged factor scores. Finally, if these determinations consistently conformed to expectation, then the original hypotheses would be supported.

To move quickly from the ideal to the reality of the site, we found no vertical trends in the artifact data, as will be described in the next section. Horizontal trends which were discovered could not be confirmed in the manner described above.

Vertical Trends

In order to obtain results which would be statistically useful, individual form distributions were not considered. Small sample sizes for forms would have led to problems of sampling error. Form groups were devised linking traditional form (type-like) categories into more general morphological/ functional classes. Major emphasis was on bifaces, given the larger sample of bifaces and the fact that bifaces are more homogeneous morphologically than non-bifaces. The latter simply means that many bifaces could be classified easily in more ways than many non-bifaces.

Biface attributes examined for vertical trends are form group, material, length, weight, lateral edge asymmetry, pink or red coloration (as evidence of heat treating), presence of potlid fracturing, cross section morphology, tip morphology, stemmed biface body edge morphology, stem basal thinning, stem width, stem length, fragment maximum dimensions, and possible function. Non-biface attributes examined for vertical trends are form group, material, length, pink or red coloration, and potlid fracturing. (Vertical distribution tables for lithic artifact attributes are included in Nance and Hurst 1978: Tables 5.6 to 5.27).

Again, none of these tables contains evidence of significant vertical trends which might be explained as due either to culture change or to the effects of mixing (artifact size differences).

Horizontal Distributions

The absence of vertical artifact trends (or, our inability to discover them) preclude any definite conclusions regarding flake and lithic artifact attribute covariation. However, horizontal artifact distributions are compared to the flake attribute distributions as described above since given the shallow deposits of the O'Neal site and a plowzone provenience for 83% of the artifacts, the only potential for discovering patterned artifact distributions might lie in the horizontal dimension.

The initial horizontal distribution analysis involved all excavated formed artifacts. Each artifact received the factor score of the square from which it was excavated, and factor scores were averaged by form group or selected attribute class. Factor 1 and Factor 2 scores were summarized for each variable, but Factor 1 produced the most variation in means which were determined and the only consistent results, and therefore only Factor 1 scores are considered in subsequent discussion.

The two-group pooled t-test was repeatedly employed to measure the significance of differences between the mean scores generated by Factor 1. This allowed many "age" comparisons to be made on various artifact attributes. (The use of this generated score introduces theoretically a slight correlation among the "observations" judged to be too small to upset significance levels seriously).

In most cases, the means vary little from one another or from zero, suggesting little covariation between "early" or "late" squares and artifact attributes. There are, however, a few statistically significant differences among biface means which might also be significant in interpreting the site's prehistory. Possible interpretations of these findings will be discussed in the conclusions; at this juncture, it will suffice to alert the reader to their existence.

Among biface groups unfinished bifaces have a higher average score than other groups, and the difference is significant in some cases. For instance, a comparison of the groups stemmed points and unfinished bifaces produced a t-value of 2.82 (with 167 df, p = .01). In terms of relative age, this suggests that unfinished bifaces tend to date later than stemmed points in the site's prehistory, assuming that the overall approach employed has some validity.

Mean scores for bifaces were divided into three weight ranges. Light artifacts (0.3 and 6.2 grams) produced a mean score of -.139, medium-weight artifacts scores -.052, and heavy artifacts (9.9 - 48.8 g) averaged .071. The light and heavy artifacts were found to differ significantly (t = 2.25; for 195 df, p = .05). These data suggest a shift from light to heavy artifacts through the site's sequence.

A parallel trend is suggested by data which summarize stemmed points by length range. Short points (1.2 to 3.7 cm long), have a mean score of -.243; medium-length points, a mean of -.154, and long points (5.0 to 6.2 cm long), a mean score of .537. The two-group pooled t-test was applied to the short and long point classes: t = 2.98, for 41 df, p = .01.

Another noteworthy finding regards biface tip morphology. This is summarized in terms of four descriptive categories: pointed, convex, straight, and irregular. Points with irregular tips produced a much higher mean score (.318) than the others. Comparing the groups "pointed" and "irregular" yielded a t-value of 2.40, significant at p = .02 for 208 df.

In order to partially assess these findings, we conducted a second horizontal artifact analysis, involving only artifacts from 42 squares for which flakes were analyzed. While artifact samples are smaller, the square factor scores were determined directly by the flake factor analysis; none was derived through linear regression based on square flake frequencies. The same variables were compared again using the two-group pooled t-test. The same trends identified for the all-artifact tables were found: unfinished bifaces have a higher mean score than stemmed points (t = 2.5, p = .05 for 63 df); heavy bifaces have a higher mean score than light bifaces (t = 1.94, p = .10 for 35 df); long stemmed points have a higher mean score than short stemmed points (t = 1.78, p = .10 for 15 df); and irregularly tipped bifaces have a higher mean score than pointed tipped bifaces (t = 1.71, p = .10 for 81 df).

One additional finding from the 42 square sample is that asymmetrical bifaces have a higher mean score than symmetrical bifaces (t = 2.65, p = .01 for 84 df). The same trend, although not significant, was found for all artifacts (t = 1.36, p = .20 for 240 df).

CONCLUSIONS

Attribute Analysis and Settlement Patterns

Square Factor 1 scores, level 1 and 2 analysis, are depicted in Fig. 5.3 in a histogram by value tenths. Dividing the square into four groups on the basis of apparent clustering, the resulting spatial patterns can be seen in Fig. 5.4. Here, each excavated square (blocks 3A-10A) is identified as to group membership: very early, early, late, and very late. It can be seen that early and very early squares tend to cluster together, compared to late and very late squares. If these temporal designations are at all accurate, they suggest compact settlement during a major early occupation, followed by more diffuse settlement across the site during later periods.

Attribute Analysis - Flake and Lithic Artifact Attribute Covariation

Most artifact attributes show little variation when projected against the flake data by square (through averaging of artifact square factor scores). However, certain biface attribute class frequencies do vary between early and late squares. Heavy bifaces, large stemmed points, bifaces with irregularly shaped tips, bifaces with lateral edge asymmetry, and unfinished bifaces all tend to occur in late squares, as compared to their counterparts: light bifaces, small stemmed points, sharply tipped bifaces, bifaces with lateral edge symmetry, and (finished) stemmed points.

If we take these two patterns to represent differing portions of the site sequence, it can be seen that they compare closely with those tentatively reconstructed through flake analysis, and that they occur in predictable sequence. In lower levels, we identified high proportions of small flakes which suggested the production of relatively small, finely made chipped stone tools. Flakes from upper levels suggested the production of larger, less finished artifacts. The composite result is that in terms of relative temporal positions, the flake assemblages are associated with tools whose manufacturing debris they resemble.

Whether these flake and accompanying artifact patterns represent an archeological sequence depends on whether the vertical trends in flake size represent culture change or mixing. This problem was discussed above, and it remains only to point out the following. If small flakes filtered down through mixing, one might expect the same tendency with formed artifacts. It could be expected that chipped stone

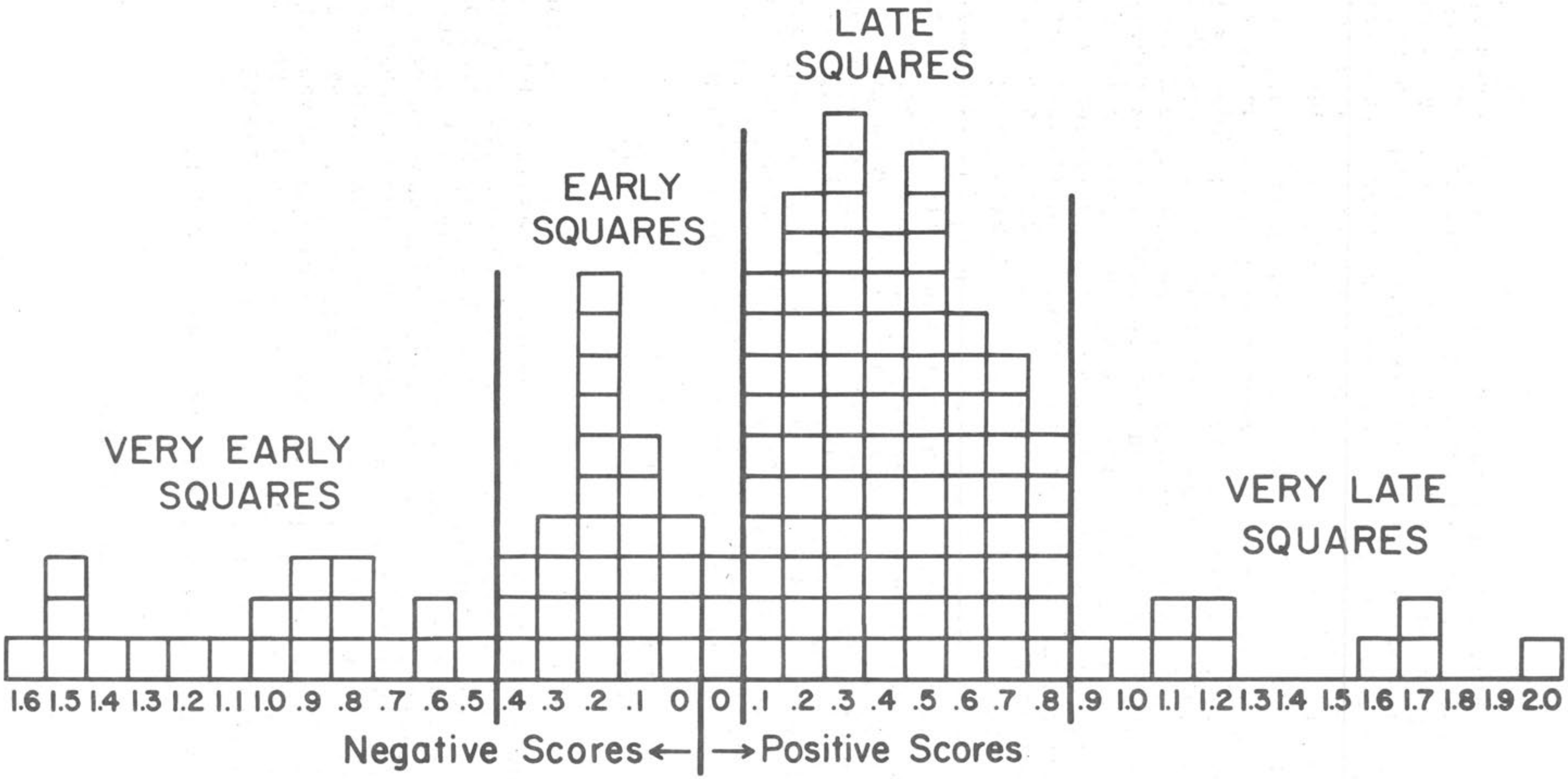


Figure 5.3. Histogram depicting all square Factor 1 scores, level 1 and 2 analysis, by value tenths.

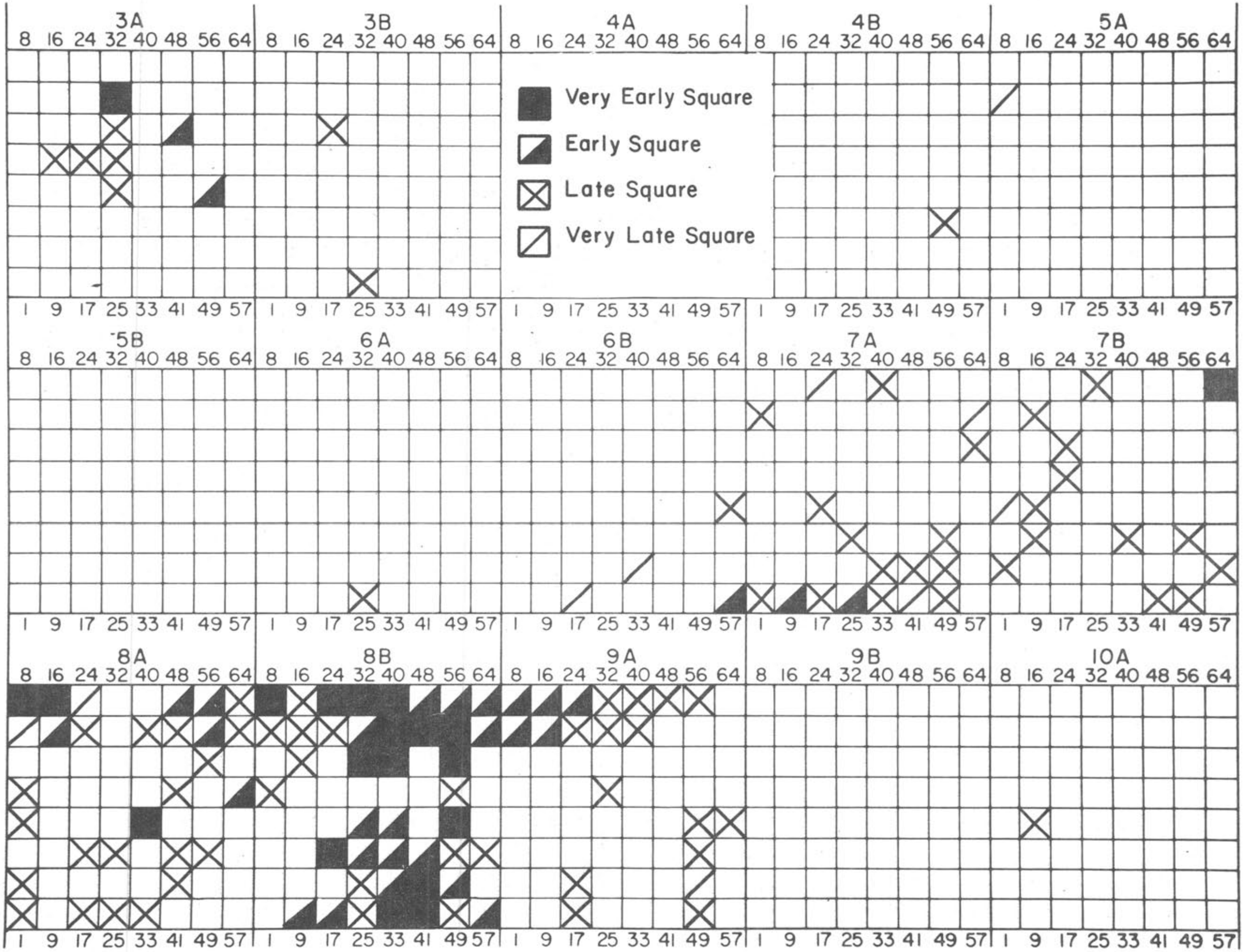


Figure 5.4. Summary of square factor scores, blocks 3A - 10A.

tool fragments would settle downward more than whole specimens. No such tendency, however, is manifest in the vertical distribution artifact tables (Nance and Hurst 1978: Tables 5.6-5.27).

If the cultural stratigraphy is not misleading, the proportionately high production of small flakes is an early characteristic on the site. And, if Factor 1 scores represent with some accuracy the relative ages of artifacts and chipping debris recovered from each square, then high proportions of small flakes and small, finely formed artifacts are associated by virtue of their similar positions in the site sequence. Factor 1 scores, however, are based on flake material proportions. We found no significant direct correlation between artifact size and flake size on a square by square basis (flakes from levels 1 and 2, only). Factor 2 mean scores (for length and weight attribute classes) did not differ significantly when assessed through use of the t-test.

The problem is complicated by the fact that the different flaking properties of different materials can affect flake size and form of completed artifacts. Correlation between flake materials and artifact sizes and morphologies is not surprising. There are no significant correlations, however, between artifact materials and flake materials.

Several archeologists have studied experimentally the relationships between flake and artifact production. These studies have all involved replication of chipped stone tools using hard and soft hammer percussion and in two cases, pressure flaking. Ahler (1975) emphasizes the differences in flake size proportions produced by manufacture of different tool forms and also by different techniques of edge preparation. Newcomber (1971), studying flakes from production of three Acheulian-like handaxes, emphasized changing flake sizes as they were removed sequentially in artifact production. Henry, Haynes, and Bradley (1976) focused primarily on flake size differences as produced by the three (above-mentioned) general flaking techniques in the production of Clovis-like projectile points.

A major difference between the data from all three of these studies and those from the O'Neal site involves the overall size ranges of flakes considered. All three studies involved the use of sieves to collect flake samples, with the smallest mesh used varying between one and 3.2 mm. During excavation of the O'Neal site, water was not available to facilitate screening of material through 1/16 inch mesh. Material was therefore dry-screened through 1/4 inch mesh. In all three experimental studies, the majority of flakes considered were in size ranges with upper limits at or below 3.2 mm. For the O'Neal site, this strongly suggests that most flakes in the deposits of the 42 flake study squares passed through the screen and were not collected. In studies by Ahler (1975) and Henry et al. (1976), sizes of pressure flakes are recorded, and indications are that most pressure flakes included in the O'Neal site flake study squares were not recovered.

Given this basic sampling difference, certain trends in the experimental data are germane to our findings. Newcomber (1971:93) found in the manufacture of handaxes, "an incremental decrease in the size of the flakes removed." Ahler (1975) found that large thin bifaces produced by soft hammer percussion resulted generally in smaller flakes than produced in the manufacture of thick bifaces by hard hammer percussion. Also, generally smaller flakes resulted from both pressure and soft hammer retouch of biface edges than from overall production of large bifaces. Henry et al. (1976) found no significant differences in flake size between those produced by hard hammer percussion (generally the first technique used) and those resulting from soft hammer percussion. However, pressure flakes, generally removed in the final stages of manufacture were significantly smaller.

In general, then, experimental data are not incompatible with those from the O'Neal site, keeping in mind the relatively restricted nature of the O'Neal site sample. An association of small finished artifacts with high proportions of small flakes and of large, incompletely finished artifacts with high large flake proportions could be expected on the basis of the studies considered.

Flake Factor Analysis and Ceramics

A total of 240 prehistoric ceramic sherds was excavated from the site; all are undecorated; 200 are clay-tempered, and 38 are tempered with sand. Comparative data from elsewhere in Alabama (e.g., Heimlich 1952; Jenkins and Nielsen 1974; Nielsen and Jenkins 1973; DeJarnette and Wimberly 1941) indicate that the clay-tempered sherds are Late Woodland or later, thereby post-dating A.D. 500, while the few sand-tempered sherds are contemporary or earlier, dating to the Early or Middle Woodland period (1000 B.C. - A.D. 500). We examined the pottery in the same manner we had treated the stone tools, in terms of the square factor scores. Mean sherd factor scores by temper were generated for the 38 sand-tempered and 200 clay-tempered sherds. The sand-tempered sherd mean score was the earlier of the two, and the difference between them was significant (sand tempered sherd $\overline{x} = -.114$, $S^2 = .636$; clay-tempered sherd $\overline{x} = .254$, $S^2 = .620$; results of the two-group pooled t-test: $t = 2.64$, $p = .01$, 236 df).

Chronology

Absolute chronological information for the O'Neal site derives from three sources: ceramic and projectile point type cross dating and three radiocarbon dates.

Ceramic data suggest that the earlier flake-biface pattern existed during the Early and/or Middle Woodland, and the later lithic pattern during the Late Woodland. Thirty-four projectile points were identified at the O'Neal site which had been defined elsewhere, and for which gross chronological ranges had been determined (e.g., Elora, Coosa, Bradley spiked [Cambron and Hulse 1975]; Types 63, 64, 89, 99, [Faulkner and McCollough 1973]). Of these, 26 types are assigned to both the Archaic and Woodland or exclusively to the Woodland period, while only 8 types are regarded as pre-Woodland. These assignments are not inconsistent with the interpretation suggested by the ceramic temper-factor score comparisons.

Charcoal from three undisturbed pits yielded these radiocarbon dates (5568 year C14 half-life [uncorrected]): 2080 ± 80 B.C. (TX-3244), 2910 ± 240 B.C. (TX-3247), and 3740 ± 70 B.C. (TX-3245). The dates may represent the earliest portion of the site sequence and do not contradict the above interpretation.

A second interpretation is offered here, however, because although the Late Woodland ceramics cluster in late factor score squares, the bifaces from these same squares are atypical of recorded Late Woodland lithic assemblages in the area. For instance, site 1JE55, a Late Woodland site located one mile downstream from the O'Neal site, was test-excavated and found to contain mostly very small chipped stone tools, predominately arrow points. This contrasts to the relatively crude and large bifaces from squares with late factor scores.

In this second hypothetical sequence, the shift in lithic debris and biface attributes is seen as occurring first, during the Late Archaic period. Woodland occupation, identified primarily through the presence of ceramic material, followed this early occupation. The covariation of sand-tempered sherds with the early (low) Factor 1 scores is seen as resulting from two different occupations concentrated on the slightly elevated ground of the site area investigated (compare Figs. 5.1 and 5.4). In short, the following sequence is suggested: (1) consolidated Late Archaic occupation producing small flakes and small, finely made bifaces; (2) later, dispersed occupation during the Late Archaic period represented by large flakes and large, relatively crude bifaces; (3) consolidated Early to Middle Woodland occupation (in the same area as the earlier Late Archaic component) represented by sand-tempered sherds; and (4) dispersed final occupation by Late Woodland groups using clay-tempered pottery.

Attribute Distributional Analysis on the O'Neal Site - An Assessment

Prior horizontal analyses of artifact distributions on sites have dealt with single site areas, (the analysis of artifacts from a single group of contiguous squares). These studies have directly measured the spatial covariation of groups of artifacts (Whallon 1972; Dacey 1973; Hietala and Stevens 1977). The procedure used is first to divide the area into blocks (combinations of contiguous excavation units) to achieve adequate artifact samples. Next, non-random, block by block distribution is assessed for each of several groups of artifacts using the variance/mean ratio. Finally, examining two groups at a time, block covariation is evaluated using the chi-square test (Whallon 1973; Dacey 1973) or some other method (Hietala and Stevens 1977). Problems inherent in this approach involve the accuracy of the variance/mean ratio as an index of non-random distribution, and the determination of block size (Hietala and Stevens 1977). The strength of this general technique is that it does deal directly with artifact spatial associations.

This approach, however, does not seem applicable where the goal is to discover and sample different occupations across an extensive site. Separated excavation areas would greatly aggravate the problem of determining block sizes and locations.

In the O'Neal site horizontal analysis, artifact spatial associations are only implicit, as artifact group associations are expressed in terms of positions in a relative sequence. One advantage of the approach used here is that it offers the potential of developing artifact sequences for sites with low artifact frequencies below the plowzone. A further benefit is that this approach directly relates debitage to artifacts, so that one can relate changes in the represented technologies of artifact production to changes in the kinds of artifacts which are left on a site.

SUMMARY

While the sequence of the O'Neal site is not entirely clear, the study has produced enough data to indicate considerable research potential for this type of site (shallow sites, where most material is located in the plowzone), given the use of statistics and attribute analysis. To view the matter with perspective: in the development of regional prehistories, local sequences can be confirmed through the study of stratified sites and the application of absolute dating techniques. Settlement patterns, however, can be understood only through consideration of most or all sites in selected localities, not just the few exceptions where deposits are stratified or undisturbed.

In summary, analysis of the O'Neal site, which is shallow, plowed, and contains low artifact densities, has produced the following information:

(1) patterns in flake attribute covariation have been found across the site involving material types, flake size, and flake morphology;

(2) vertical shifts in flake attributes point to a basic shift in the stone flaking technologies employed at the site;

(3) covariation of flake and biface attributes suggests a general lithic artifact sequence, built on a framework of horizontal and vertical flake attribute patterns; and

(4) assignment of relative age designations to all excavation units has led to tentative information on shifting sizes of occupation areas.

The implication of these findings is that the techniques employed, when refined and substantiated, might be useful in elucidating chronologies, technologies, and settlement sizes on multi-component, shallow sites.

In the present context of contract archaeology, sites like the one described here are often dismissed as insignificant, even when eligible for contract funding. We suggest that more attention be given to similar sites, particularly in contract contexts, so that field and laboratory techniques can be developed and the capacity for acquiring information from shallow, plowed archaeological sites increased.

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THE DEVELOPMENT OF SEDENTARY VILLAGE COMMUNITIES IN NORTHERN WEST VIRGINIA: THE TEST OF A MODEL

by
John W. Fuller

INTRODUCTION

While much archeological research has been done on the evolution of complex sedentary communities such as towns and cities few studies have addressed the problem of community pattern dynamics and nucleation in initial sedentary settlements. Because these earliest and smallest sedentary forms have been overlooked, a set of evolutionary principles governing their development is currently needed in archeological theory.

This study focuses on development of small scale nucleated sedentary communities and their evolutionary relationship to dispersed sedentary communities in the upland portion of northern West Virginia during Late Woodland-Late Prehistoric times (roughly 500 B.C. to A.D. 1000).

Research Area

The northern Panhandle region of West Virginia (Fig. 6.1) was chosen for this study for the following reasons:

1. numerous Late Prehistoric agricultural village sites are well known through surface survey and excavation (e.g., Mayer-Oakes 1954, 1955; Dunnell 1962, n.d.);

2. although poorly recorded, Woodland occupations are known to exist from features and deposits found in excavated Late Prehistoric villages (Dunnell 1962; Mayer-Oakes 1955; Nale 1963); these occupations are thought to have been agricultural;

3. strong evidence favors a cultural continuum in the area from Early Woodland through Late Prehistoric (Mayer-Oakes 1955; Dunnell 1962); and

4. modern agricultural use, along with shallow upland soils, make the area ideal for systematic surface survey and controlled surface collection (cf. Dancey 1973, 1974).

The study area, consisting of parts of Ohio and Brooke Counties, West Virginia, is located adjacent to and east of the Ohio River. The area is a highly dissected upland plateau with valley-ridge systems ranging in elevation from 640 to 1300 feet.

Figure 6.1. Location of study area in northern West Virginia.

Terminology

Although some terminology developed in the study of community patterns is useful here, no precedents have been established for applying this terminology to small scale sedentary occupations (cf. Beardsley 1956; Willey 1956; Sanders 1956; Sears 1956; Sanders and Price 1968; MacNeish 1972; Parsons 1972). Therefore preliminary definitions of *community*, *village*, and *hamlet* are necessary before discussing the specific problem addressed in this study.

The archeological definition of *community* is based upon the sociological notion that internal relationships exist in human groups which are part of the same socio-economic system. If circumstances permit, all community members and all domestic activities occur within the same settlement. Given other social and/or economic conditions, community members and domestic activities are spread throughout a region in separate settlements. In the latter case, the community is unified through redistribution and special shared activity sites, such as Streuver (1968) has documented in the Illinois Valley.

In either case, the community consists of a redundant set of functions or activities, along with unique communal structures or areas (such as burial mounds, cemeteries, plazas, or roads). Archeologically, the community is identified as a corporate unit by the presence of a cohesive stylistic assemblage from one or more settlements.

A *village* is a community type which consists of a contiguous association of living structures and activity areas. Each village community usually contains its own internal special purpose area or structure, such as a cemetery or plaza. A village is not simply a smaller form of a town or city, for villages lack functional specialization found in towns and cities.

The term village emphasizes the compact and agglomerated nature of living activities and multiple occurrence of structures and functional areas within the settlement. Thus a village is here defined as a cluster of domestic debris which can be subdivided into a contemporaneous set of unique and redundant functional units.

Important in this definition is the emphasis upon the village as a residential unit consisting of identical (in a classificatory sense) structures *and* activity areas used simultaneously. The number of people or the number of structures is not decisive here. What *is* important is the multiplicity of contemporaneous activity areas. In other words a Monongahela occupation of 6 houses constitutes a village as does an Onondaga Iroquois longhouse with 15 earthovens and 20 flint working areas.

Although a village may be a community, in that an entire community may reside at one site, this situation is not the case with the occupation type referred to here as hamlet. In this study, a hamlet is considered to be that domestic site which is part of a dispersed sedentary community. Therefore, a hamlet is only a portion of an entire community. A hamlet lacks the multiplicity of activity areas of a village and consists only of a single set of functions and structures. Accordingly, a hamlet is defined here as a cluster of domestic debris which cannot be subdivided into redundant functional units.

EVOLUTION OF EARLY SEDENTARY COMMUNITY PATTERNS

The archeological literature implicitly recognizes that in some areas villages evolve from hamlets. The process responsible for this evolution is generally considered to be population growth and enlargement of individual hamlets (e.g., Smith 1972; Ritchie and Funk 1973:355-365). An alternative explanation suggests that villages form by the combination of numerous hamlet occupations at a single location during a very short time period (Fig. 6.2).

The first model, termed the Growth Model, stipulates that sedentary community pattern changes result from increasing population pressures. According to this idea, Woodland hamlet occupations increased in size through time by addition of more residences and duplicate activity areas -- a growth made possible by gradual significant increases in resource extraction per unit of area. The village became the common community form since all occupations eventually consisted of redundant living and activity areas. Sometime during this evolution, cemeteries located within the village, rather than burial mounds located externally, became the burial custom. The growth process as described here would not be expected to have occurred completely at any one site because occupations were relocated periodically (ca. every generation) when the productivity of local resources declined.

The alternative model accounting for village formation, termed the Nucleation Model, stipulates change in the distribution and structuring of a given population in the environment, but not a necessary change in population. According to this model, villages form by the relatively rapid clustering or aggregation at a given location of several hamlets. Such a spatial compaction of existing occupations requires an increased energy flow from the environment in a proportion similar to that described for the Growth Model. The major distinction between the two models is not their supportive energy systems, but rather the "quantum leap" in occupation size found in nucleation (Fig. 6.3).

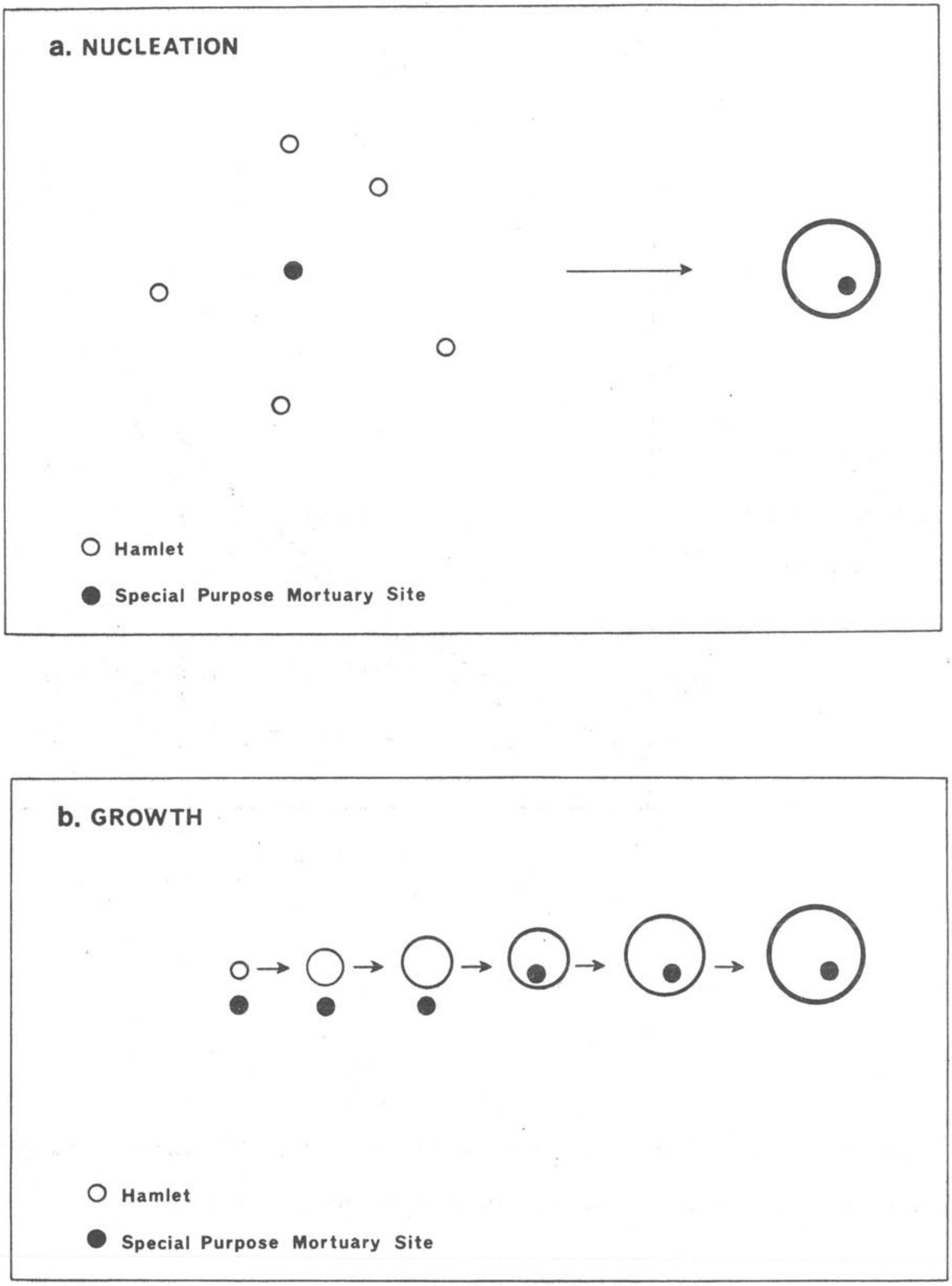


Figure 6.2. Models of village formation by (a) nucleation and (b) growth.

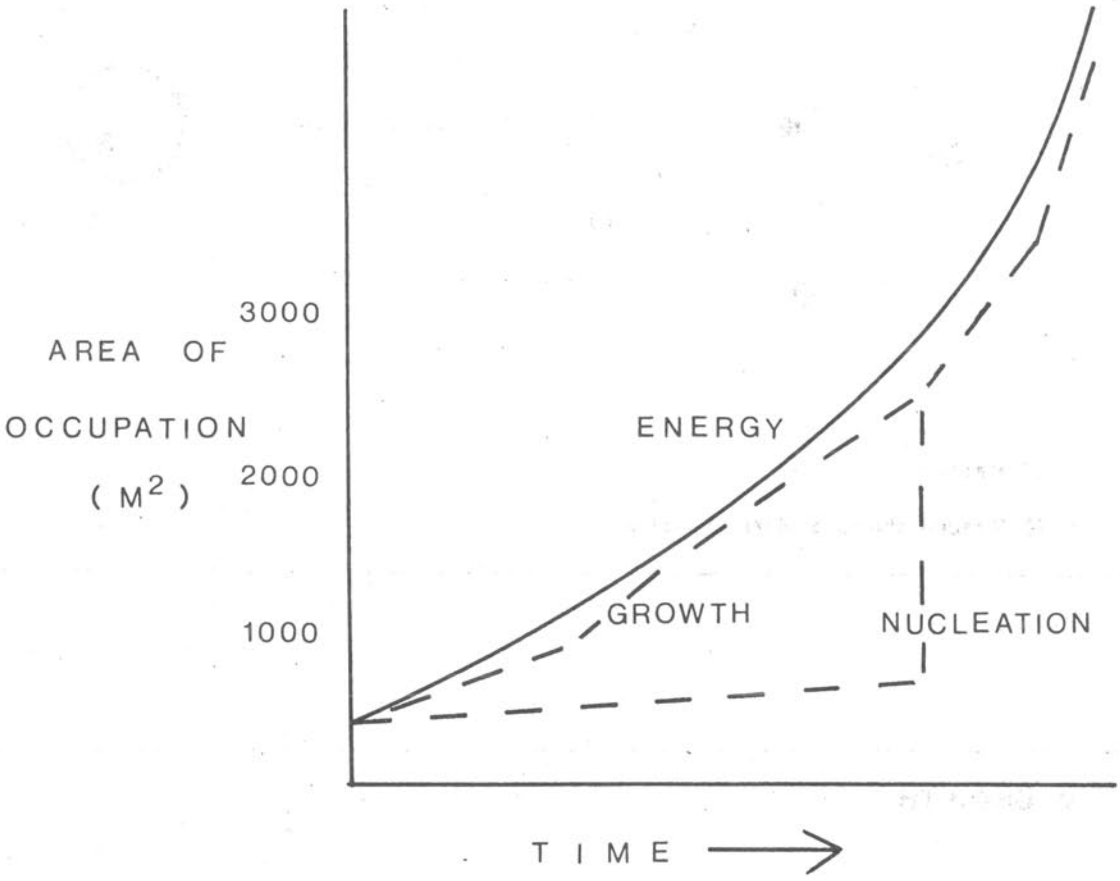


Figure 6.3. Rate of increase of occupation area for the hypothesized growth and nucleation models, shown with speculated energy increase.

If the Growth Model accounts for changes in community patterning in the Upper Ohio Valley, then Woodland and Late Prehistoric occupations would be found in all sizes, ranging from hamlets through small villages to villages with a dozen or more structures. In this case, a broad range in size would be found, due to the frequent movement of domestic sites and the consequent abandonment of living sites in various stages of the growth process.

In that the Nucleation Model stipulates that occupations increase in size by adding more than a minimal occupation unit -- the hamlet -- no small-sized Woodland or Late Prehistoric villages would be expected to be found in the Upper Ohio Valley. According to this model, communities would consist either of hamlets or of villages with no fewer than 5 sets of redundant functional areas. (The minimal expected size in this region is based on existing archeological reports, such as Dunnell n.d., Mayer-Oakes 1954.)

FIELD WORK AND ANALYSIS

The implications of the Growth and Nucleation Models were tested in 1971 and 1973 by intensive systematic surface survey. The strategy entailed locating a sample of Woodland and Late Prehistoric occupations by a stratified random sampling of the research area and determining regional distributions of artifactual remains (see Dancey 1974; Dunnell and Fuller 1974). Size and structure of occupations were assessed by controlled surface collection.

Initial results consisted of a sample of variously-sized artifact clusters containing varying proportions of Woodland and Late Prehistoric ceramics. Surface material at all sites included utilized and non-utilized lithic pieces, ceramics, and minor quantities of shell and bone. Ceramics included early Woodland "Half Moon" (grit tempered), Middle Woodland "Watson" (limestone tempered) and Late Prehistoric "Monongahela" (shell tempered) wares (see Mayer-Oakes 1955 for type descriptions); some clusters contained examples of all these types.

Area of surface debris for the smallest clusters measured about 400 m^2; intermediate-sized clusters measured between 600 and 1200 m^2, and the largest clusters ranged upwards from 2000 m^2 (Fig. 6.4).

CHRONOLOGICAL AND FUNCTIONAL CLASSIFICATIONS

Testing the Growth and Nucleation Models required constructing a relative chronology for the area. Of help in constructing seriations was the ceramic typology developed in the Upper Ohio

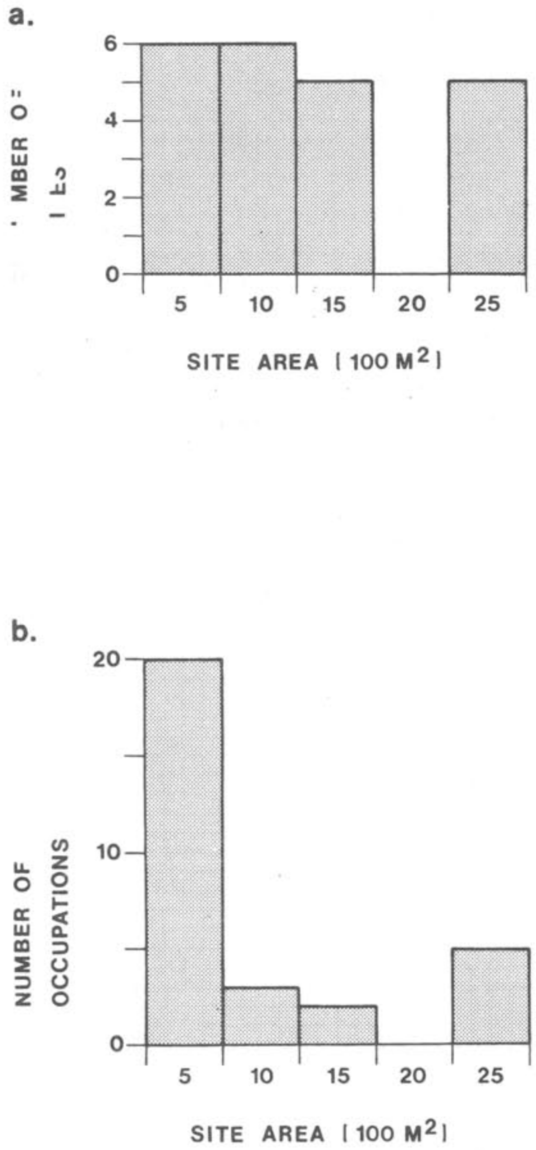


Figure 6.4. Frequency histogram of (a) sites by total site area and (b) occupations within sites by site area.

Valley by Mayer-Oakes (1955) and others in the early 1950s. Seriations at that time were complicated by the inclusion of assemblages from a wide geographic range, with too much stylistic variation (cf. Dunnell 1970; Mayer-Oakes 1955:180-183). However, the typology based on intersection of dimensions of surface treatment and temper (essentially those used by Mayer-Oakes) was successful as a basis for constructing seriations judged to most useful chronologically for restricted local areas (Fig. 6.5).

Functional classification, to compare occupations and areas within occupations in terms of artifact use, was performed. Classifications were constructed at two scales: whole object according to structure (e.g., sherd, flake, core, cobble, etc.); and part-of-object (wear patterns and their characteristics).

The purpose of these two functional classifications was to create units proposed as being culturally significant, whose spatial patterning could be used in depiction of community or occupation patterns. This was achieved through contour density mapping using the Synagraphic Mapping System, SYMAP (Dougenik and Sheehan 1976). Each cluster was mapped in terms of discrete-object and cultural-attribute densities. Thus, maps showing densities of sherds, flakes, limestone tempering, cordmarking or any combinations of these categories could be produced for each site.

The interpretation of the resulting maps yielded four site patterns: single cluster, low density (Fig. 6.6); single cluster, high density (Fig. 6.7); multi-cluster, low density (Fig. 6.8); and multi-cluster, high density (Fig. 6.9).

Single cluster, low density patterns are relatively small and conform with the definition of a hamlet: they consist of a single debris area, presumably related to a single structure or activity sphere at the site. Figure 6.6 shows the surface of a site in terms of densities of all artifactual debris; this site clearly displays the single aggregated characteristics of a hamlet. Maps of other whole artifact categories (e.g., ceramics, flakes, etc.) at this particular site have a similar appearance.

The single cluster high density pattern is generally about four times as dense as the low density cluster pattern and occupies about twice as much space. In spite of their larger size and increased artifact density, these sites clearly consist of a density pattern with one central peak or maximum and thus are properly considered hamlets. Figure 6.7 shows one such site, mapped in terms of all artifactual debris (counts of lithics, ceramics, shell, and bone). The small extraneous clusters on the left and lower left side of this map appear to be part of the main cluster. These clusters are found to accompany all high density hamlets but are absent (or not visible) in low density hamlets.

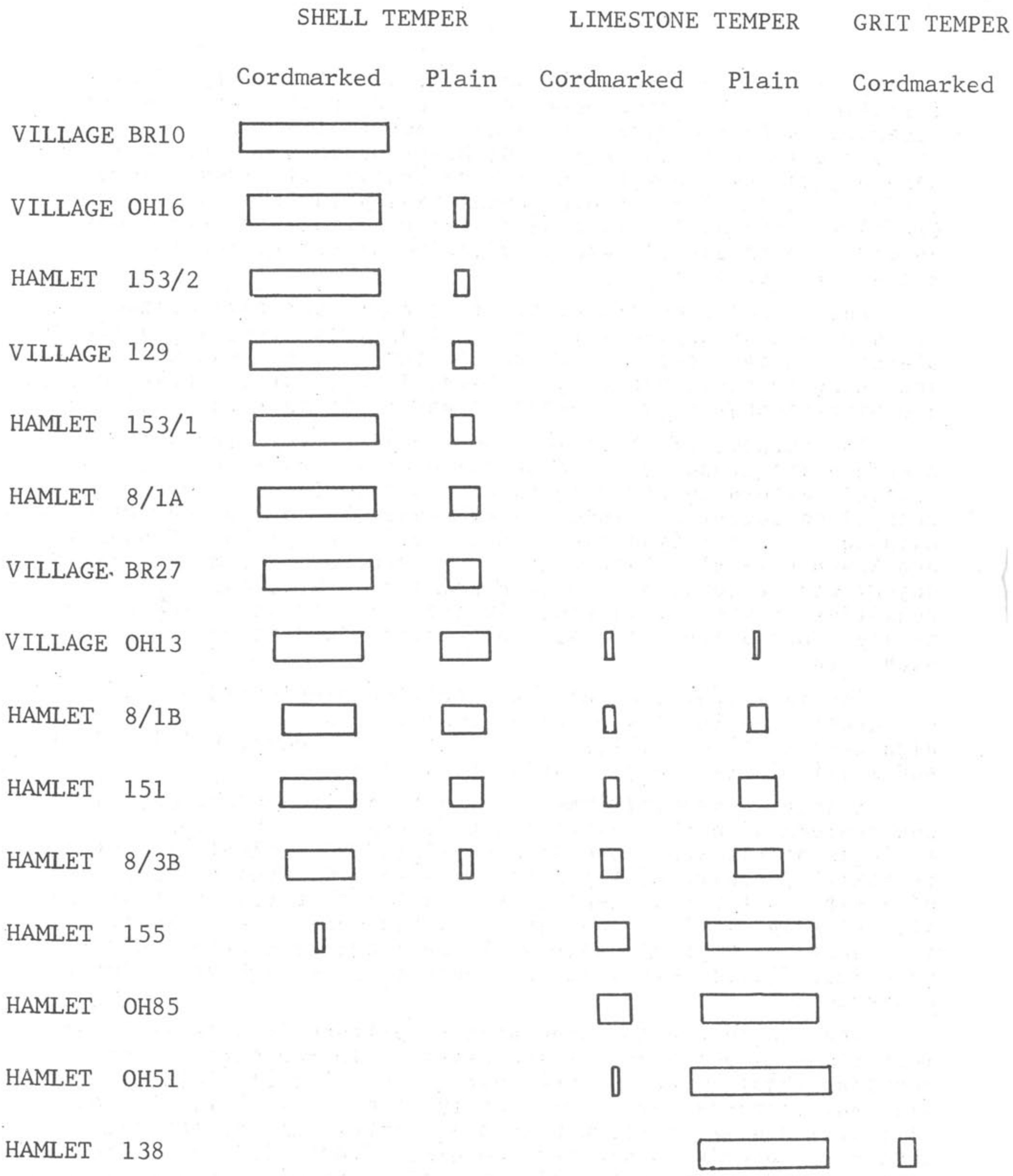
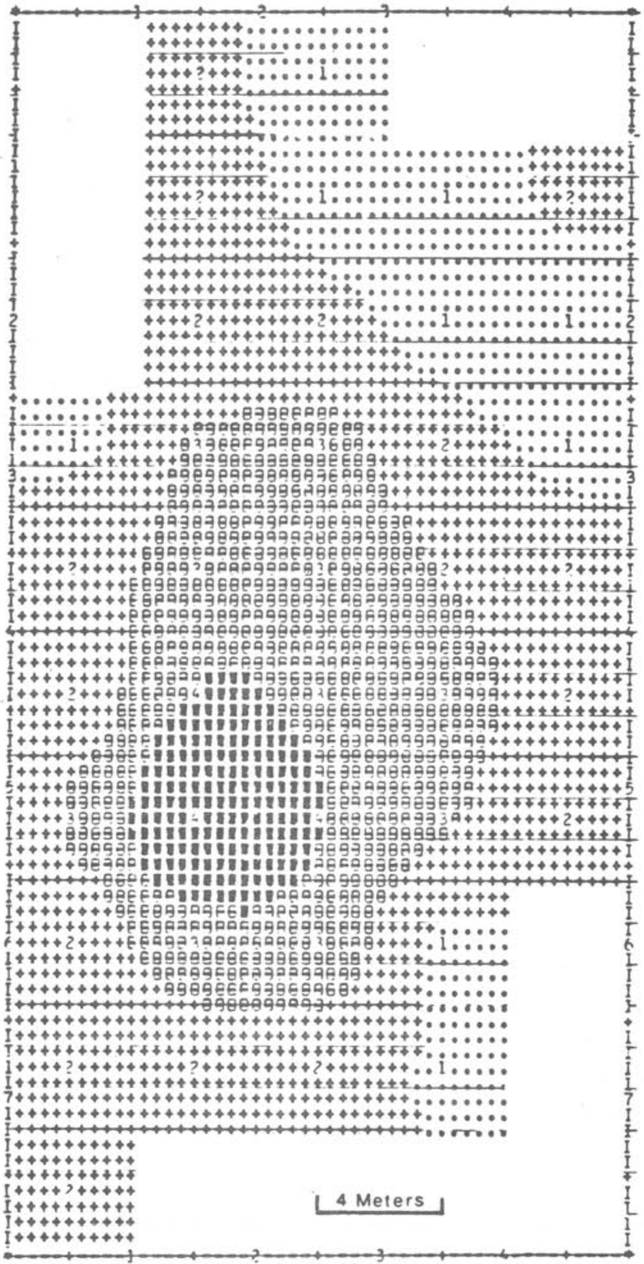


Figure 6.5. Seriaton of Ohio and Brooke County sites, West Virginia.



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* SYMAP * DEPARTMENT OF GEOGRAPHY



ALL ARTIFACTS

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DATA VALUE EXTREMES ARE            0.00        56.00

     LEVEL        1           2           3           4
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   MINIMUM       0.00        4.07       19.35       34.62
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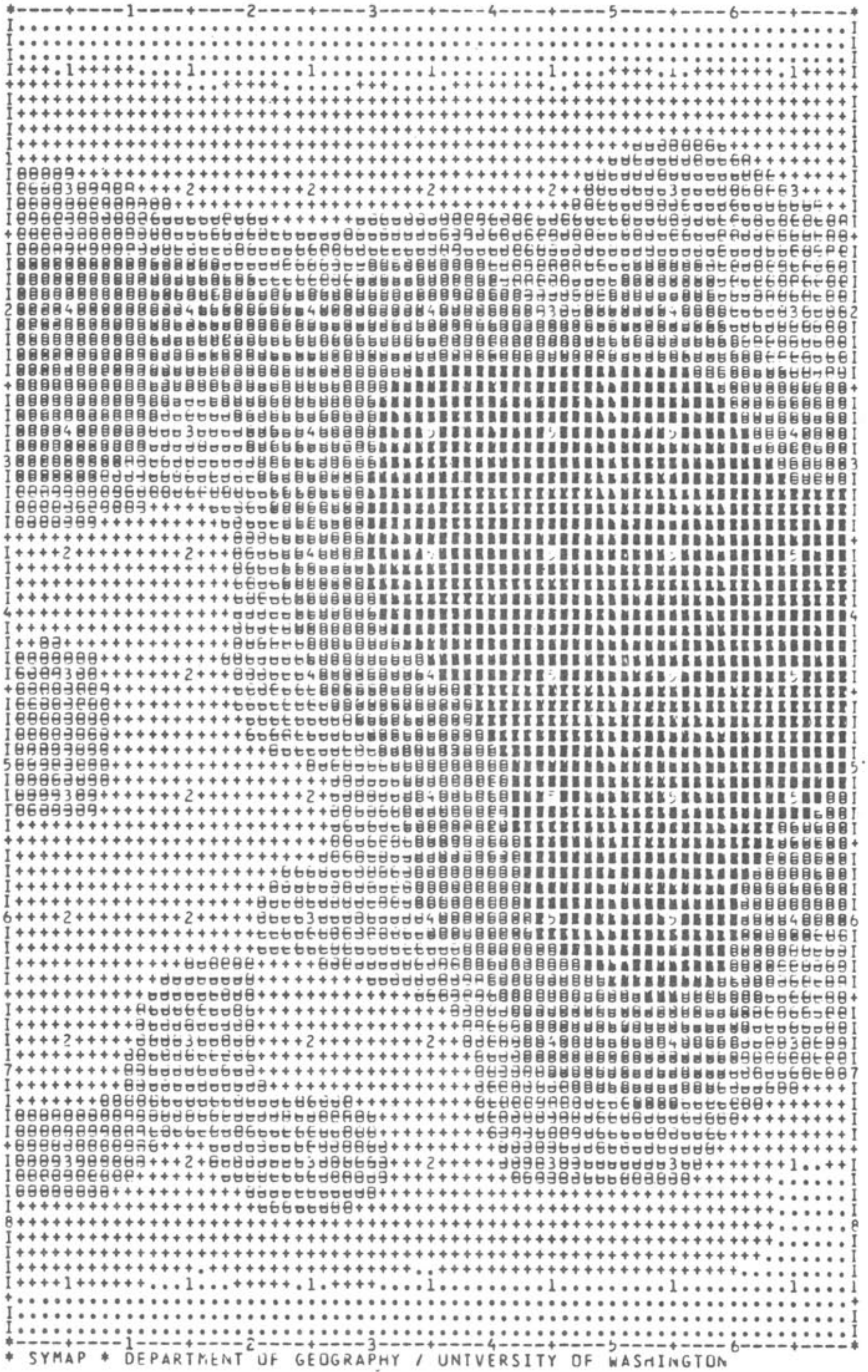
Figure 6.6. Single cluster pattern, low density.



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4 Meters

ALL ARTIFACTS

46 OH 133-2 SCHUETZ FARM

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FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1            2            3            4            5
          ================================================================
             .........    +++++++++    888888888    888888888    █████████
             .........    +++++++++    888886336    888888888    █████████
  SYMBOLS    ....1....    ++++2++++    888838888    888848888    ████5████
             .........    +++++++++    888888888    888888888    █████████
             .........    +++++++++    888888888    888888888    █████████
          ================================================================
  FREQ.         15           16           15           16           15

  MINIMUM      0.00          .50        17.00        37.00        70.00
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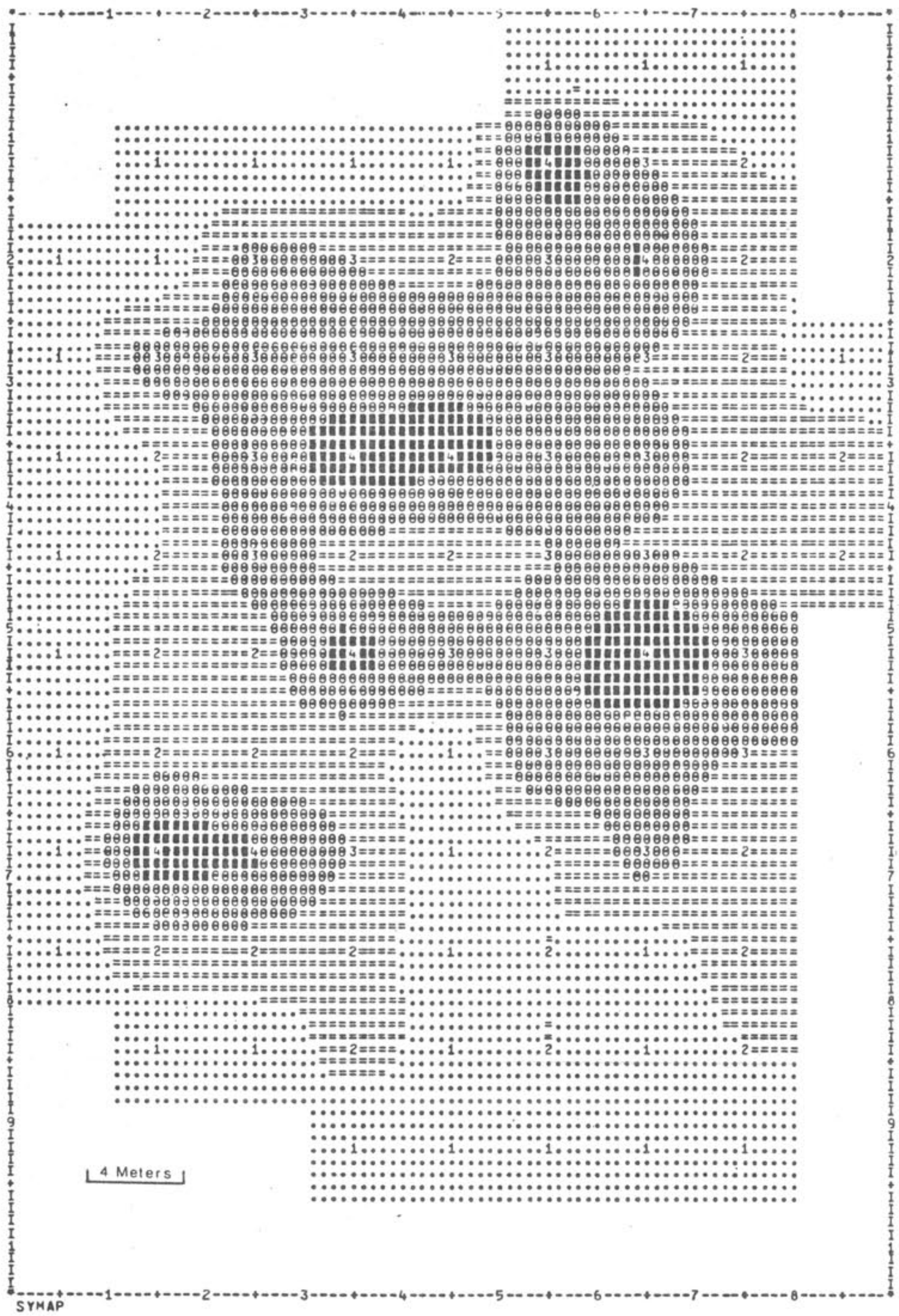
Figure 6.7. Single cluster pattern, high density.



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ALL STONE ARTIFACTS
        46 OH 138


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MINIMUM        0.00       2.00       5.00       9.00
MAXIMUM        2.00       5.00       9.00      14.00
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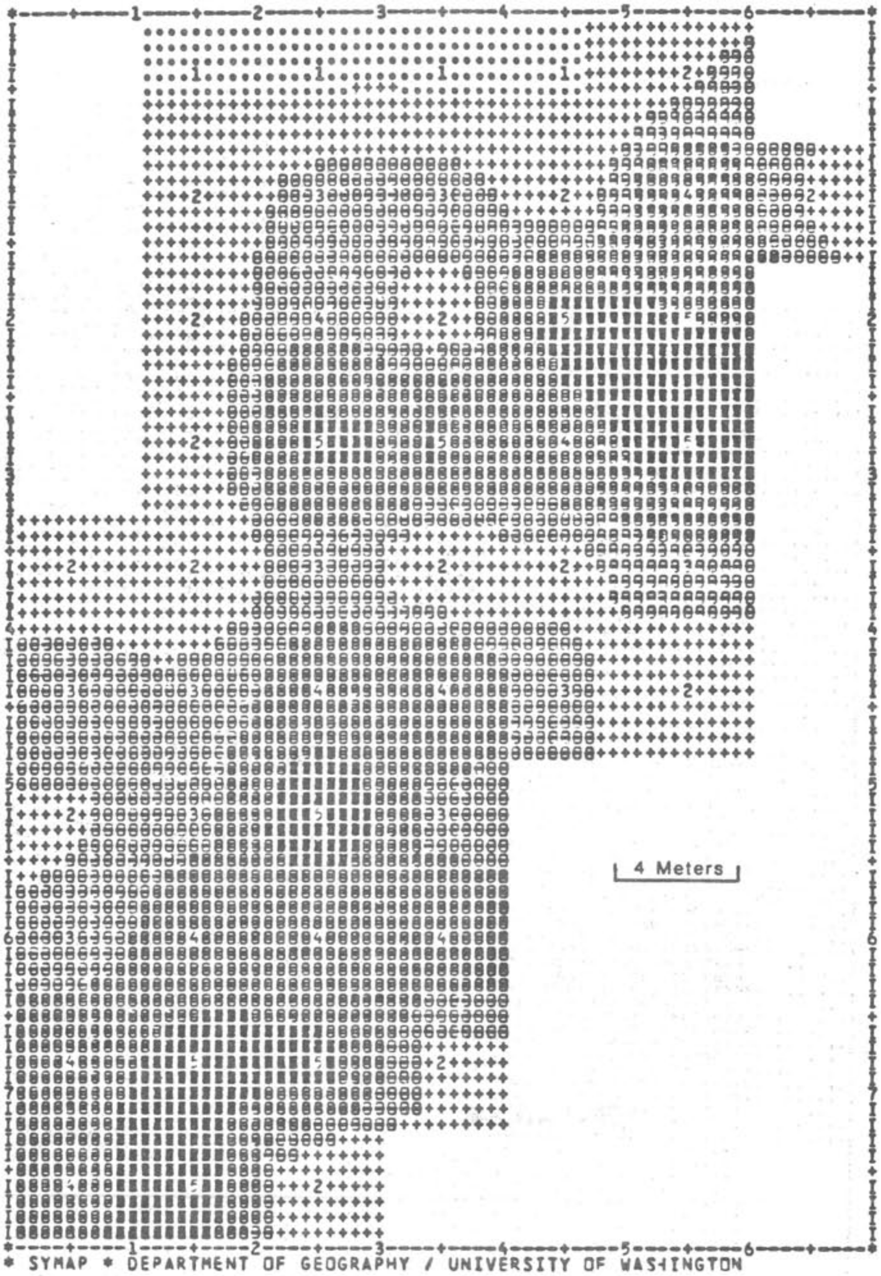
Figure 6.8. Multi-cluster pattern, low density.



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   7.7 SECONDS FOR MAP


ALL STONE ARTIFACTS

   SITE  46 OH 129  WILHELMS GARDEN



  FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
    LEVEL         1          2          3          4          5
             ******************************************************
              .........  +++++++++  000000000  000000000  IIIIIIIII
              .........  +++++++++  000006000  000000000  IIIIIIIII
    SYMBOLS   ....1....  ++++2++++  000030000  000040000  IIII5IIII
              .........  +++++++++  000000000  000000000  IIIIIIIII
              .........  +++++++++  000000000  000000000  IIIIIIIII
             ******************************************************
    FREQ.         4         15         10         10          9


  MINIMUM       0.00        .50       5.50       8.00      12.00
  MAXIMUM        .50       5.50       8.00      12.00      15.00
```

Figure 6.9. Multi-cluster pattern, high density.

The high density of certain hamlet occupations, such as the one depicted in Fig. 6.7, is attributed to a very long occupation or long series of frequent reoccupations. Abundant ceramic remains are found on the surface of these sites, representing the entire Woodland and Late Prehistoric sequences. Surface assemblages from low density hamlets present a more restricted ceramic type inventory, indicating that sites were occupied for a shorter duration.

Multicluster pattern sites (Figs. 6.8 and 6.9) also occur with both low and high surface densities. It was unclear from the outset whether these were single or multiple occupations. However, mapping the clusters using time-related (ceramic designs and temper) and functional attributes, it became clear that these sites are sets of contemporaneous, related sub-clusters or clusters of contiguous but chronologically different occupations.

SYMAPs of ceramic modes and types indicate that some of the complex clusters (such as shown in Fig. 6.4) consist of stylistically identical, thus contemporaneous, sub-clusters. As a group such clusters occur late in the chronological sequence. Redundant characteristics of the functional areas at these sites and their late chronological position support the conclusion that these dense multi-cluster patterns are villages.

Figure 6.9 maps the density of all stone artifacts collected from the surface of approximately one-quarter of a site. While densities of all cultural material range up to 76 items per collection unit (16 m^2) densities of lithic items per unit range from 0 to 15. Although the remainder of this site is covered with buildings and roadways, reports from competent amateurs indicate that the spread of artifactual debris is towards the lower right in this figure. The structure of this upland village site would appear to be two parallel rows of houses (also see Mayer-Oakes 1954; Dunnell n.d.), rather than the circular arrangements found in most nearby Pennsylvania areas (e.g., Butler 1939; George 1974).

The low density complex cluster consists of stylistically dissimilar sub-clusters, judged to be different aged components, each of which corresponds to the occupation pattern defined for hamlets, (i.e., they cannot be subdivided functionally). These complex sites, such as that shown in Fig. 6.8, include wide ranges of ceramic types. Such sites are presumed to be locations of hamlets which were abandoned and later reoccupied adjacent to or superimposed on previous occupations.

APPLICATION OF THE GROWTH MODEL AND NUCLEATION MODEL IN THE STUDY AREA

As stated in a previous section, in order for the Growth

Model to be accepted as the process of village formation, remains of villages of all sizes would have to be found in the study area. No evidence was found during survey for the existence of very small sized villages (two to four redundant functional areas). Instead, occupations are either hamlets or villages of more than five living structures and activity area sets. In short, conditions for application of the Growth Model are not met in the uplands of the West Virginia Panhandle.

Although evidence obtained so far suggests strongly that the Growth Model fails to account for the formation of village communities, it might be proposed that the "missing" growth stages of villages occurred in environments outside the study area or occurred within (and thus are obscured by) a single settlement. Overwhelming evidence for a cultural continuum in the area mitigates against the former possibility (Mayer-Oakes 1955; Dunnell 1962); the thin character of village deposits, an indication of short-term use of these settlements, negates the latter possibility. In short, the Nucleation Model describes the developmental sequence in this area more accurately than does the Growth Model.

During the Woodland period, hamlet communities were confined mainly to the western half of the West Virginia Panhandle (Fig. 6.10). Within this time period the geographic distribution of hamlets becomes more restricted, and some areas were abandoned, never to be reoccupied. In Late Woodland-Early Late Prehistoric times, the first communities nucleated from pre-existing hamlets. This development occurred first in the uplands in the central portion of the study area (Fig. 6.11; Fig. 6.5).

During the Late Prehistoric period, villages also developed on the alluvium of the tributaries of the Ohio River; but villages never developed or spread in the western upland portion of the Panhandle. This area continued to be occupied by hamlet communities of long duration (Fig. 6.12). During this developmental period, use and construction of burial mounds ended; for the first time, burials are found in occupational assemblages, as cemeteries became incorporated within the village site.

It must be pointed out that the number of communities involved in the change in this area is probably small. Possibly all nine villages recorded in the central uplands and 20+ hamlets recorded in the western uplands constitute remains of two separate communities. The present chronology is not accurate enough to reflect what contemporaneities may exist in the area.

In spite of the small scale of community pattern change documented for this area, regularity of change and its confinement to particular micro-environments is unmistakable. Given similar environmental conditions and archeological remains in the rest of northern West Virginia and southwestern Pennsylvania, it seems likely that the nucleation process re-

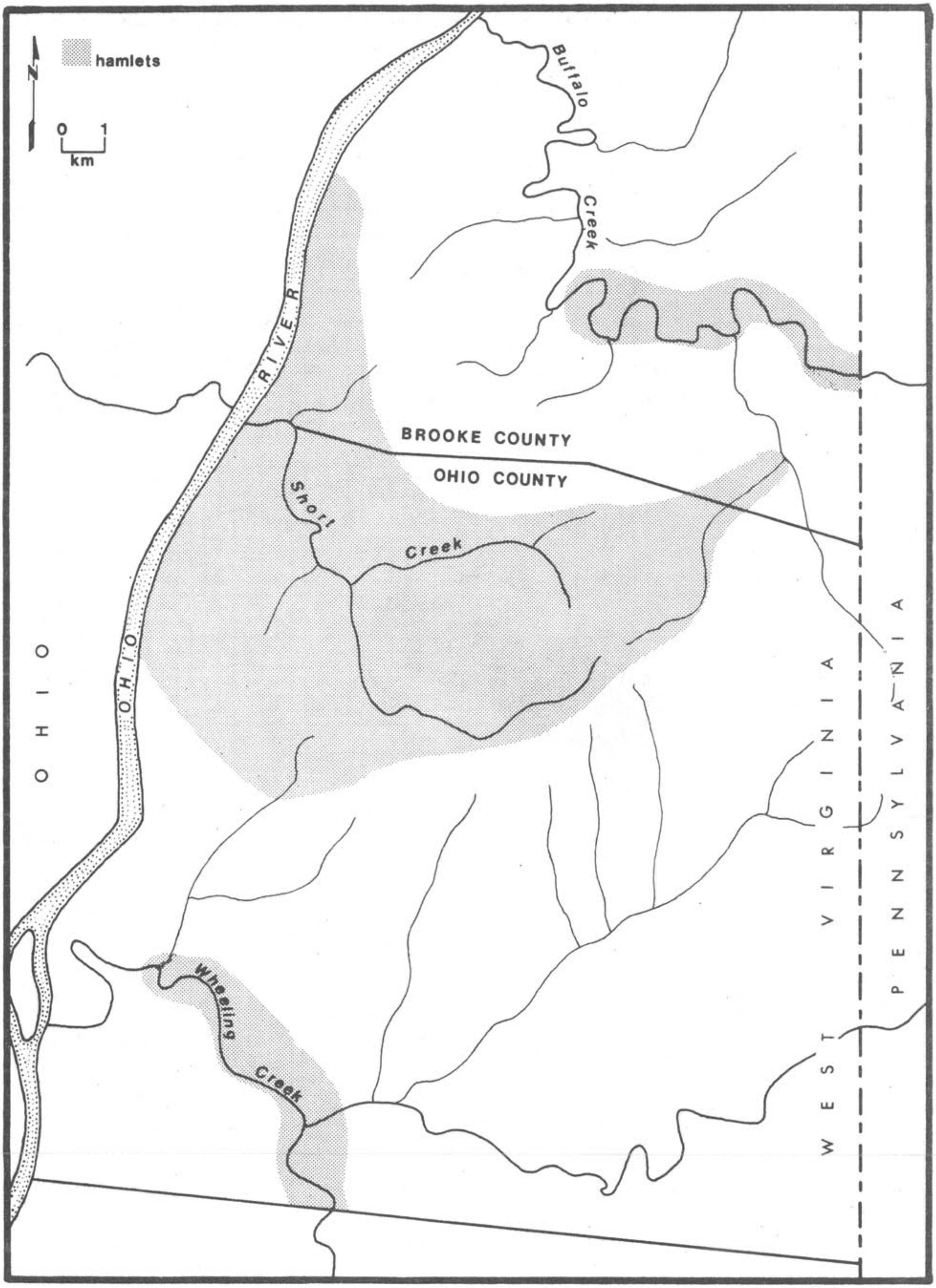

Figure 6.10. Distribution of Early and Middle Woodland hamlets.

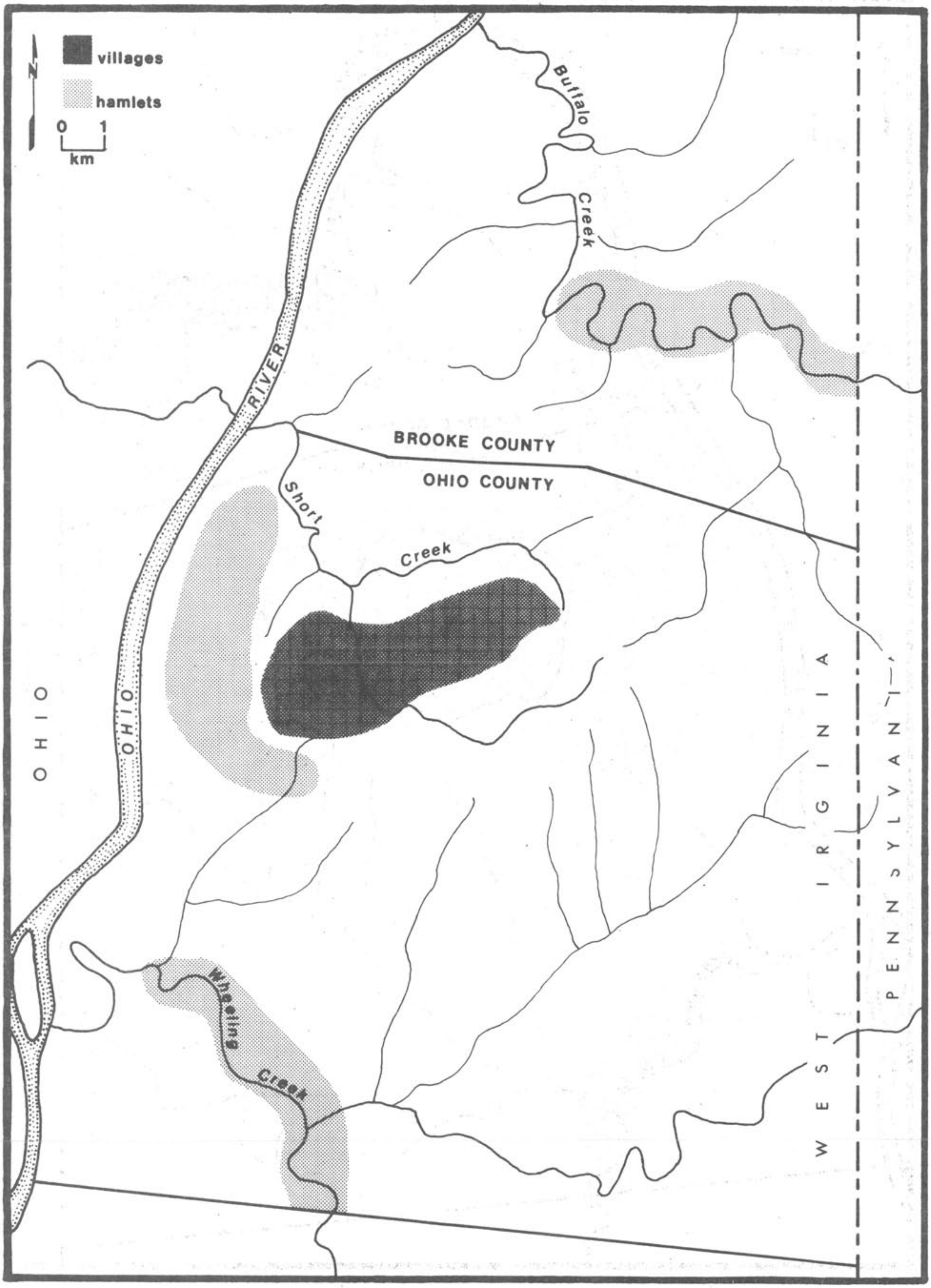

Figure 6.11. Distribution of Late Woodland-Late Prehistoric hamlets and villages.

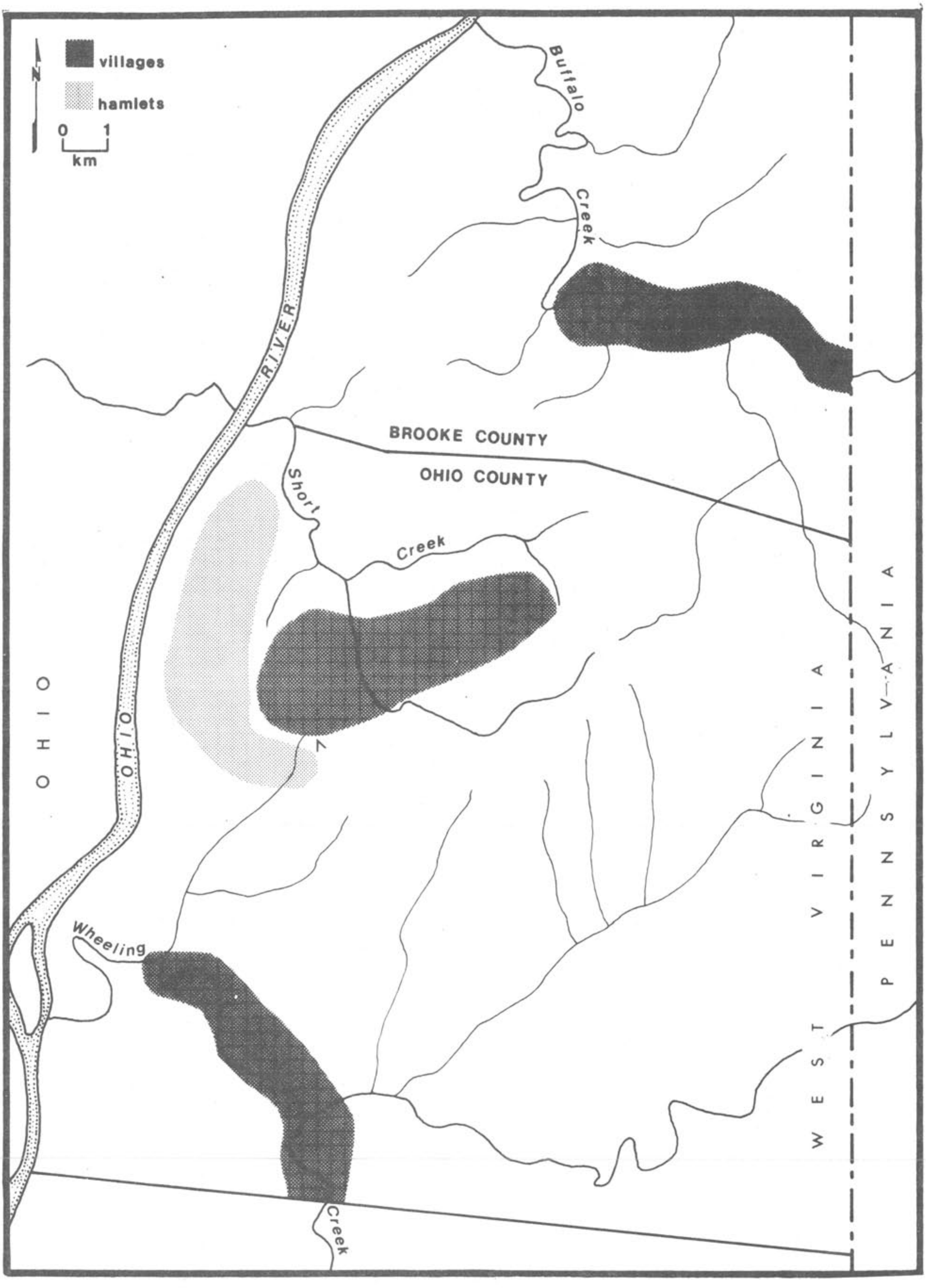

Figure 6.12. Distribution of Late Prehistoric hamlets and villages.

occurs in the entire Monongahela culture area.

Village communities in the Upper Ohio Valley constitute a dramatic spatial re-organization. Their formation in special restricted spaces, along with a marked increase in ceramic remains (containers) in village deposits, suggests that increased food production and consequent storage was an important factor in the change.

Dispersed communities are separated spatially to spread consumers widely throughout a marginal resource area. This distribution insures that sufficient energy is available for each member occupation. If a technological improvement, such as evolving agriculture in the Upper Ohio Valley, elevates the extractive efficiency per unit of area to a sufficiently critical level, spatial separation of the dispersed community becomes inefficient and unnecessary, and nucleation occurs. Because it allows more effective manipulation of the subsistence economy and its social order, such compaction confers an immediate adaptive advantage.

Maintenance of a nucleated community requires production of more energy per unit area, but less energy per capita than does a dispersed community. Thus, by exploiting an area only a fraction of the size of the former dispersed community, the nucleated village community derives the same, if not more, energy, and simultaneously economizes on costs of redistribution and transportation.

Changes in community patterns depend on availability of sufficiently high energy densities. Therefore, changes should occur earliest in the micro-environments most suitable to the predominant aspect of the subsistence economy.

Examination of environmental parameters in the West Virginia region clearly reveals that several have a distribution similar or complimentary to that of the chronological occurrence of nucleation. Agricultural suitability, length of growing season, succession character, and resource radius are variable in the region. However, these parameters combine most favorably in the central uplands, where nucleation occurs earliest (Table 6.1).

The central uplands feature "average" modern crop suitability (Pohlman 1937), a long growing season, wide resource accessibility, and a moderate rate of second growth succession. Although certainly not ideal in comparison to many areas of the eastern United States, these factors qualify the central uplands as slightly superior to the creek bottomlands. The latter areas have "above average" croplands, but more restricted resource areas (essentially only the flat bottoms of the deep valleys), shorter growing seasons, and a higher rate of second growth.

AREA	NUCLEATION ORDER	CROP SUITABILITY	GROWING SEASON	RAINFALL	SOIL	Exploitable Resource Area
Central Upland	First	Average	Best	Better	Sandstone	Unrestricted
Creek Bottom	Second	Above Average	Better	Better	Alluvium	Restricted
West Uplands	None	Inferior	Best	Good	Limestone	Unrestricted
East Uplands	No Occupation	Below Average	Worst	Best	Sandstone	Unrestricted

Table 6.1. Environmental Parameters Affecting Modern Agriculture (Based on Pohlman 1937).

Growing season and crop suitability are important controlling factors, accounting for the absence of villages in the western uplands. Hamlets continue to occupy this area up to the end of the sequence. Given the continual adaptation of cultigens and agricultural economies in this region as a whole, nucleation would have eventually occurred in the western uplands according to the model being developed here. However, the entire Monongahela region was abandoned about A.D. 1600, presumably due to European influence further east.

The below average agricultural suitability and shortest growing season in the eastern uplands and lowlands (Fig. 6.11) made this area unsuitable for occupation for almost 2000 years. Neither villages nor hamlets are found here, although isolated projectile point finds indicate that the area was used.

SUMMARY

In sum, the Nucleation Model accommodates archeological data from the northern West Virginia Panhandle. The key elements of the model may be stated as follows:

1. Nucleated sedentary communities result from rapid compaction of existing dispersed sedentary communities;

2. A critical energy level per unit of resource area is required before nucleation can occur; absence of this necessary level keeps a community dispersed;

3. The overall effect of nucleation is greater efficiency in acquiring and distributing resources; and

4. Nucleation confers a rapid advantage in certain favorable micro-environments and is adopted earliest in those areas.

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ADDENDUM

After this paper was completed, another form of pictorial display of the data became available. This program, called SimPic (Simple interface to Picture), uses the data output of the SYMAP program and plots a three-dimensional view of the density distributions. The vertical exaggeration, viewing distance, and orientation of the image can easily be modified with several control cards.

Figure 6.13 shows ceramic densities at site 46 OH 133/1; the view is from the northwest. Figure 6.14 shows the same data displayed with SYMAP. (This site occurred at the edge of a field, only its northern 2/3 being collected; inspection of nearby plowed fields confirmed that the occupation did not extend more than 10 meters to the south.) Both Figs. 6.13 and 6.14 clearly show the hamlet structure of this cluster.

Figure 6.15 shows a portion of a village occupation, the same that is shown in the main test in Fig. 6.9. The three-dimensional view shown here is of ceramic densities, while Fig. 6.9 is of lithic densities. The contrast between village and hamlet structure is readily apparent by comparing the SimPic plots in Figs. 6.13 and 6.15. Such continuous contour depictions are very useful in displaying detailed variations in structure, but are not as accurate as SYMAP in showing the locations of structural elements within an artifact cluster.

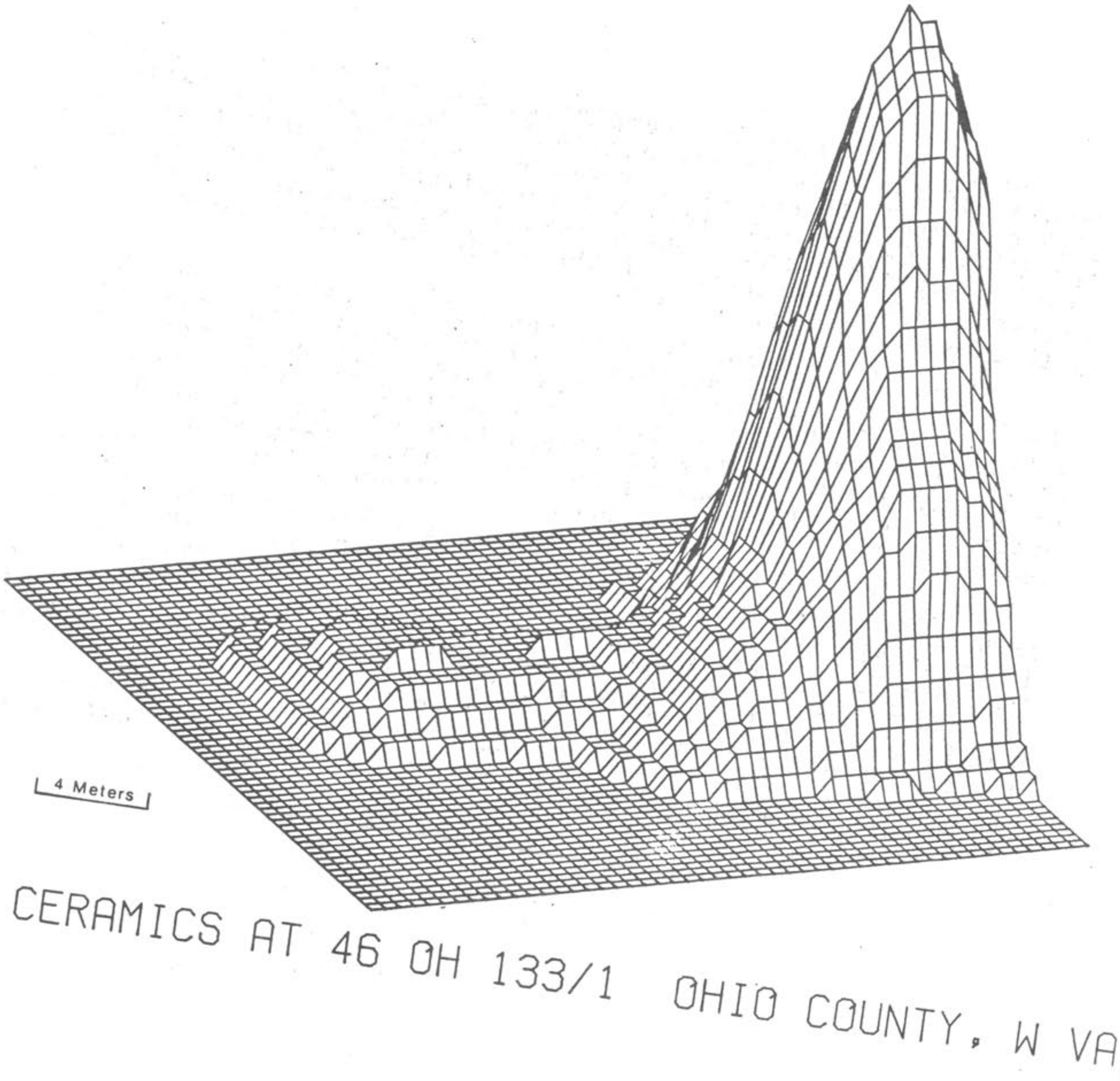
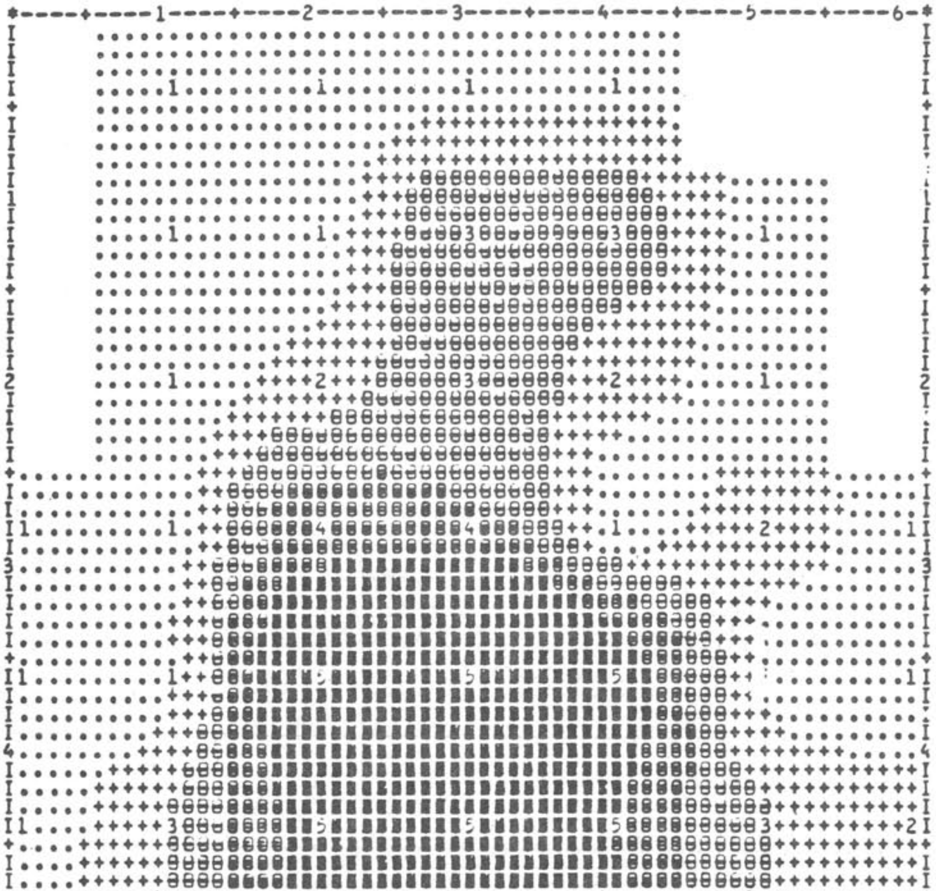


Figure 6.13. Three-dimensional depiction of ceramic densities at a hamlet.



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* SYMAP * DEPARTMENT OF GEOGRAPHY / UNIVERSITY OF WASHINGTON



ALL CERAMICS

    46 OH 133/1   SCHUETZ FARM



FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1          2          3          4          5
          ==========================================================
           .........  +++++++++  ØØØØØØØØØ  ▒▒▒▒▒▒▒▒▒  █████████
           .........  +++++++++  ØØØØØØØØØ  ▒▒▒▒▒▒▒▒▒  █████████
  SYMBOLS  ....1....  ++++2++++  ØØØØ3ØØØØ  ▒▒▒▒4▒▒▒▒  ████5████
           .........  +++++++++  ØØØØØØØØØ  ▒▒▒▒▒▒▒▒▒  █████████
           .........  +++++++++  ØØØØØØØØØ  ▒▒▒▒▒▒▒▒▒  █████████
          ==========================================================
  FREQ.         18          4          5          2          6

 MINIMUM      0.00        .50       2.00       5.00       9.00
 MAXIMUM       .50       2.00       5.00       9.00      36.00
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Figure 6.14. SYMAP of ceramic densities, the same data as shown in Fig. 6.13.

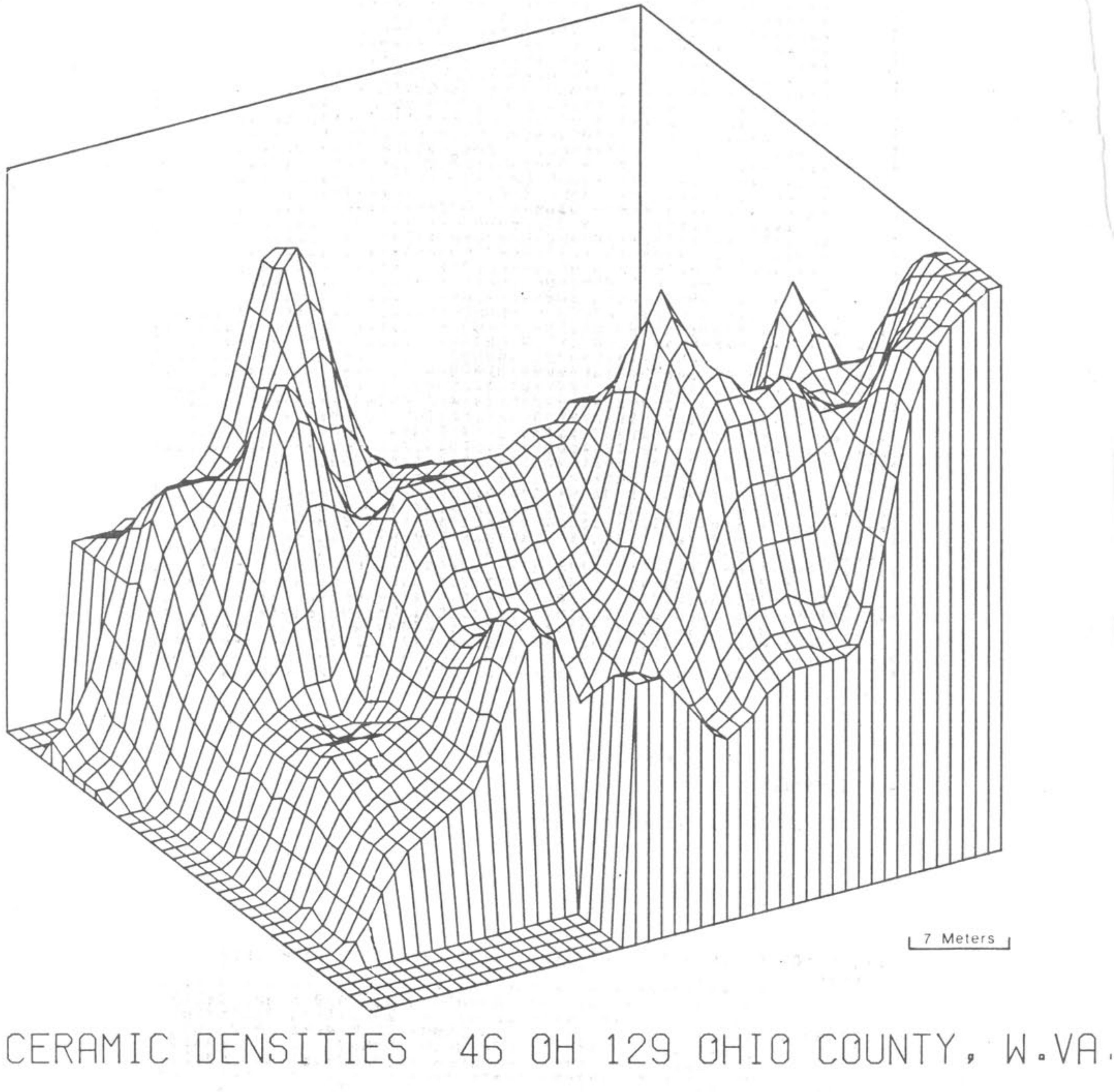

Figure 6.15. Three-dimensional depiction of ceramic densities from a portion of a village.