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Alternative Models, Alternative Techniques: Variable Approaches to Intrasite Spatial Analysis

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Spatial patterns among artifacts over an archaeological site can be very important to the archaeologist. They can be used not only in traditional ways to reconstruct the activity areas, tool kits, and lifeways of past peoples, but also to formulate and test hypotheses on the state and organization of past cultural systems and natural environmental systems.

The potential of artifact patterns to serve in these manners has increased dramatically in the last ten years through advances in two areas. 1) Our better understanding of how archaeological records are formed and organized have provided a set of bridging principles and boundary conditions for assigning meaning to artifact patterns and for inferring the states taken by variables within past behavioral-environmental systems. 2) Advances in analytic procedures for recognizing spatial patterns among artifacts have broadened the range of forms of spatial variation that are "visible" to the archaeologist and available for interpretation.

If theory building and explanation in archaeology are to proceed efficiently and accurately, however, it is necessary to integrate these new insights into

The stimulation for this paper and much of its form derive from the conversations I have had with Robert Whallon and Michael Schiffer over the past several years. Robert Whallon taught me to ask a critical question: what techniques are most appropriate for analyzing a data set, in making assumptions consistent with its structure. I would not have answered this question in relation to spatial analysis in the way I have here, however, without the insight that Michael Schiffer has shared with me on the variable effects of formation processes from site to site. Larry Keeley helped me to broaden my understanding of the probable uses of Upper Paleolithic artifact classes and to interpret the Pincevent data. James Dunn and William Darden helped me to clarify my thoughts on the application of factor analysis and ITREG to similarity coefficients. Dan Puckett and David Waddell provided technical assistance in the computer digitizing and visual display of the Pincevent data. Funds for computing were provided by the Department of Anthropology, Fulbright College, at the University of Arkansas. To all of these persons and institutions I say thank you very much.

formation processes and analytic procedure. *It is necessary to develop a theoretical framework that allows the forms of organization of particular archaeological records to be described in terms that facilitate specification of the particular kinds of spatial analytic techniques that are appropriate for analyzing them.* In any given context, only some analytic methods are appropriate for revealing artifact spatial patterns within an archaeological record. These are methods that imply, by their algorithmic procedures, certain assumptions about the nature of formation and organization of the record that are compatible with those aspects of its actual mode of formation and organization that are of interest to the researcher. Only these methods will reveal generalized spatial patterns having behavioral or other relevant meaning. Thus, in more general terms, it is necessary to develop a theoretical framework facilitating *choice* of analytic technique so that logical consistency is maximized between technique and relevant aspects of data structure (see Carr, chapter 1).

One possible framework that can be developed for this purpose is a series of models of intrasite organization of artifacts and artifact types, where the models are components of *entry models* (see Carr, chapter 2) that link data to technique. In particular, the organizational models would have three characteristics. 1) In combination, the models would inventory all general forms of organization of artifacts and artifact types that might logically occur in various environmental and behavioral contexts (e.g., ratio-scale, ordinal-scale, nominal-scale, or polythetic forms of artifact type coarrangement) along various behavioral and formation-relevant dimensions of variability (e.g., form of coarrangement of types, overlapping vs. nonoverlapping artifact set structure). 2) They would be mathematical in nature, facilitating the linkage of each model to the assumptions made by particular analytic techniques and, thus, to techniques themselves. 3) Each model would be associated with a particular set of formation processes that could have generated the form of organization specified by it, thus linking each model to particular natural environmental and behavioral contexts and to specific data sets. Using models of this kind with some knowledge about the environmental and behavioral context of an archaeological site and the formation processes responsible for it, it would be possible to associate the site (or a portion of it) with one or a few mathematical models of its organization. This association, in turn, would suggest the one or several techniques most likely appropriate for its analysis.

The process of modeling various possible forms of organization of artifacts within sites and linking those models to analytic techniques and to formation processes will help the researcher maximize concordance between data structure and technique in particular circumstances. It also, however, should reveal general deficiencies in the techniques available for analysis and in our understanding of formation processes. Clarke (1968, pp. 32-34; 1972, pp. 1-10) and Haggett and Chorley (1967, pp. 19-26) have emphasized the importance of modeling for linking data to theory in a manner encouraging theory building;

modeling can also serve, however, to link data structures to techniques in a manner encouraging the development of analytic techniques in fruitful directions.

This chapter is the second of a series of three papers aimed at integrating recent advances in analytic procedure with our understanding of formation processes through the modeling of archaeological organization and the development of needed spatial techniques. The first paper (Carr, 1984) presents one mathematical model of organization of artifacts within archaeological sites—presumably that organization which is most common. Also, a model of the organization of artifacts within the "behavioral domain" of past events, and an enumeration of the formation processes transforming that behavioral organization into archaeological organization, are provided. Most quantitative spatial analytic methods currently used in intrasite archaeology are then assessed for their logical consistency with the model of archaeological organization, and thus, their appropriateness of application. In the course of the paper, procedures for the methods are summarized. Methods for assessing the form of arrangement of artifacts in space (clustered, random, aligned), for determining whether artifact types are coarranged, and for delimiting single and multitype clusters are considered. Finally, a new technique that allows assessment of whether artifact types are coarranged and that is more consistent with the model of archaeological organization is developed. This technique is *polythetic association*.

This paper develops a broader range of models of possible intrasite archaeological organizations. It then associates these organizations with some formation processes that might generate them and some analytic techniques most consistent with them. The technique of polythetic association is expanded to include several varieties concordant with the different models of archaeological organization. These models and techniques are illustrated using data from the Magdalenian reindeer hunting camp, Pincevent habitation no. 1, in the Paris basin, France (Leroi-Gorhan & Brézillon, 1966). The models and techniques pertain to the process of defining only the degree of coarrangement of artifact types over space, not the form of arrangement of artifacts or the boundaries of clusters.

To provide a context for these discussions and analyses, this paper also summarizes and evaluates the traditional goals of intrasite spatial analysis and calls for an expansion of their scope. It also evaluates the potential that three logical-operational frameworks for carrying out intrasite spatial analysis have for facilitating logical concordance between data and technique.

The final article of the series (Carr, 1986) discusses the necessity, in some cases, of screening intrasite arrangements of artifacts prior to their analysis with the techniques discussed here or other ones. In particular, it is argued that the spatial arrangement of an artifact class (especially ubiquitously distributed ones) can be a palimpsest which is attributable to multiple, overlaid but spatially nonparallel formation processes. In these circumstances, spectral analysis, Fourier analysis, and spatial filtering techniques can sometimes be used to dissect the palimpsest into subglobal component distributions, each of which is attributable to a more homogeneous range of formation processes. Each component can then be analyzed separately from the others, along with other artifact classes that are distributed in a similar fashion, using techniques that are more closely tailored to the particular nature of the distributions and their formation processes.

BASIC ASSUMPTIONS AND PHILOSOPHY OF ANALYSIS

Quantitative intrasite spatial analysis using modern methods of geography and mathematical ecology (Clark & Evans, 1954; Greig-Smith, 1952, 1964) had its beginnings (Peebles, 1971; Whallon, 1973) prior to the time of great concern over and documentation of archaeological formation processes. The subdiscipline is now in only the initial stages of integrating this new information on formation processes and modifying standard designs of intrasite research for concordance with them. As may be expected, a diversity of opinions occur in current literature as to the proper *goals* of and *logical-operational framework* for intrasite spatial analysis. The following section discusses these issues and attempts to resolve some of them.

Evaluation and Expansion of the Goals of Intrasite Spatial Analysis

Traditional Goals

In the early 1970s, two sets of goals of intrasite spatial analysis became formalized. One occurred at the operational level, concerned with defining relationships between artifacts in the archaeological domain. The second occurred at an inferential level, concerned with reconstructing past activities in the behavioral domain.

Operational goals. At the operational level, intrasite spatial analysis was undertaken in order to define four characteristics of artifact distributions. These are 1) the form of arrangement of artifacts of each functional type (scattered randomly over space, aggregated into clusters, or systematically aligned); 2) the spatial limits of single-type clusters, if they exist; 3) whether different artifact types are similarly or differently arranged (e.g., do their frequencies among grid cells covary), regardless of their form of arrangement; and 4) the spatial limits of multitype clusters, if the types exhibit both clustering and coarrangement (modified from Whallon, 1973).

Inferential goals. The operational goals of intrasite spatial analysis were designed to allow its inferential goals to be met. The four characteristics of artifact distributions were defined in order to allow the reconstruction of 1) the spatial limits of "activity areas," 2) the organization of artifact types into "tool kits," and thereby 3) the kinds, frequencies, and arrangement of activities that occurred within a site.

The focus of early spatial analyses on reconstructing the kinds of activities that occurred within a site and their frequencies and arrangements was a particular manifestation of a broader traditional goal of archaeology: to reconstruct past lifeways (Taylor, 1948). Activity and lifeway reconstructions as the endproduct of spatial analysis typified European studies in the 1960s and 1970s (e.g., Leroi-Gourhan & Brézillon, 1966, 1972; de Lumley, 1969a, 1969b) but were also apparent on the American side (e.g., Chang, 1967, pp. 231-232; Freeman & Butzer, 1966; see Kent, 1985 for a similar criticism of later ethnoarchaeological studies). The focus on activity reconstruction was also spurred on by the interest of New Archaeologists in documenting and analyzing phenomena at a level of inference higher than that of the event: the structure and dynamics of past *behavioral systems* (Binford, 1964; Struever, 1968, p. 287). Spatial analyses by Binford et al. (1970), Whallon (1973), Goodyear (1974), and Price (1975) clearly illustrate this concern.

Expansion of the Inferential Goals of Intrasite Spatial Analysis: Reconstruction of Formation Processes and Investigation of Behavioral-Environmental System States

Early quantitative studies of intrasite spatial organization focused on the reconstruction of only a portion of the phenomena that currently are within the potential scope of intrasite research. They also encompassed only a portion of its potential goals. An expansion of the range of intrasite spatial analysis is proposed in this section. In particular, it is suggested that *formation processes in general*, as opposed to only activities, can be the object of reconstruction efforts. It also is proposed that this broader range of processes can be used to document and analyze the structure and dynamics of *both* past *behavioral systems* and past *natural environmental systems*, as opposed to only the former. These potential aims of intrasite spatial analysis are implicit in the rationale for current ethnoarchaeological studies (e.g., Binford, 1977a, 1981a), but have not been explicitly considered or realized in archaeological spatial analyses drawing upon such studies.

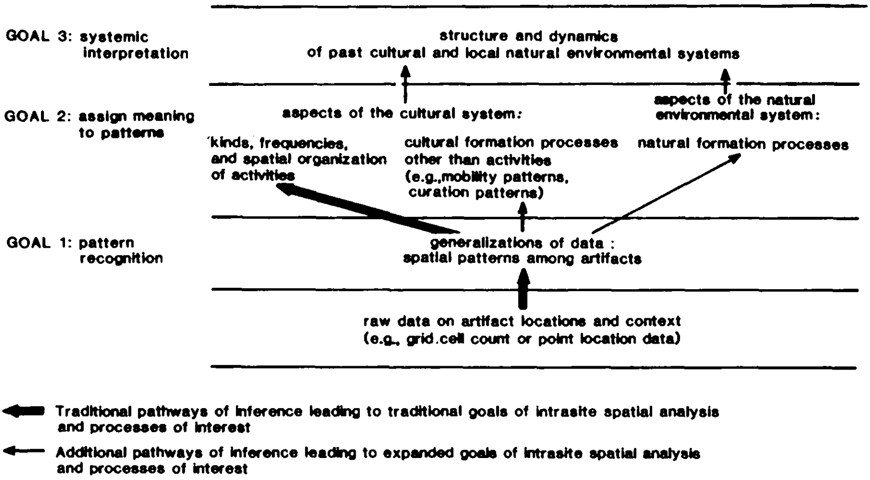
To begin, it is necessary to clarify terms.

In this chapter, the term *formation process* is used to refer to both cultural and natural formation processes. Cultural formation processes are viewed, in the manner of Binford (1981, p. 200), as components of the behavioral system. They include not only specific *activities* leading to landscape modification, but also other organizational processes, such as mobility patterns or curation patterns, that comprise a behavioral system. To distinguish these other cultural formation processes from activities, per se, the term *extra-activity cultural formation processes* is used. Hopefully, this term will provide a means for resolving current ambiguity in the notion of cultural formation processes and clarify Binford's (1981a) and Schiffer's (1983, 1985) opposing viewpoints.

The broader range of processes and goals that potentially can be encompassed by an intrasite spatial analysis, and their placement within a chain of logical inferences, are shown in Figure 1. (Here, an inductive chain of inferences is shown; the deductive case would be similar.) This construct can be explained as follows. At the lowest level of abstraction are raw data in the form of artifact point locations or counts of artifacts within grid cells over the site. At a higher level are various generalizations about the data (test implications in deductive mode). These include measures of the degree of aggregation or dispersion of an artifact type, its degree of coarrangement with other types, and other kinds of patterns. These patterns can be derived from the data with visual or quantitative methods, but in either case, the search procedures should be made explicit and justified in ways to be described later (see Carr, chapter 2). Spatial patterns, in turn, can be used to infer information about *three* kinds of formation processes. This information includes 1) the occurrence, frequency of occurrence, and spatial organization of past *activities*, as evidenced by "activity areas" and "tool kits"; 2) the occurrence of *extra-activity cultural formation processes*, such as curation patterns that are definable by the polythetic organization of artifact types (see pp. 347-355); and 3) the occurrence, magnitude, and spatial organization of *natural formation and post-depositional processes.*

Correct inference of these nonobservables from spatial patterns involves the application of theoretically and empirically relevant bridging arguments—definitional assumptions (Binford, 1977b)—which allow behavioral or natural meaning to be assigned to them. Recent studies of archaeological formation processes in the fields of ethnoarchaeology, experimental archaeology, taphon-

Fig. 13.1. Inferential pathways leading to traditional and expanded goals and processes of interest in intrasite spatial analysis.



omy, and geoarchaeology, as well as formal deductive approaches to the subject matter, are useful in this regard. They document or suggest some of the kinds of arrangements of archaeological remains that different activities and formation processes can generate (Ascher, 1968; Binford, 1977a, 1977b, 1978, 1983; Schiffer, 1972, 1973, 1975a, 1975b, 1976, 1982; Schiffer & Rathje, 1973; Yellen, 1974, 1977; O'Connell, 1977, 1979; Gould, 1971, 1978; Gifford, 1978, 1981; Wood & Johnson, 1978; Butzer, 1982).

The activity areas, tool kits, activities, extra-cultural formation processes, and natural formation processes that are reconstructed for a site in turn represent or can be used to infer certain past behavioral and environmental *conditions* that are critical to formulating and testing hypotheses about the structure and dynamics of past behavioral systems (Binford, 1977) and natural environmental systems. Again, appropriate bridging principles provided by ethnoarchaeology and other fields are required. For example, the kinds, frequencies, and spatial organization of activities that occurred in a site can be used to infer its seasons of occupation (Binford, 1978), site functions (Styles, 1981), community population (Cook & Heizer, 1968; Yellen, 1977) household interaction patterns, community kinship, and social organization (Brose, 1968; Wiessner, 1982), etc. Extra-activity cultural formation processes can be used to infer community population size (Schiffer, 1972, pp. 161-162) or site seasonality (Binford, 1978a). The reconstructed processes may *directly represent* (as opposed to allow inference of) certain parameters of the behavioral system, such as pattern and degree of mobility. Natural formation processes can be used in a similar manner to reconstruct various conditions of the natural environment (Wood & Johnson, 1978).

These inferred or represented behavioral and natural environmental conditions constitute the states taken by variables comprising the behavioral-environmental system under examination. Thus, they can be used to suggest or test hypotheses pertaining to *relationships* among variables of that system, or cultural environmental systems in general. An example is the relationship between regional population densities and community organization or mobility within particular natural environmental contexts.

Therefore, extra-activity cultural formation processes and natural formation processes, as well as activities, can be integrated within intrasite spatial research. Their identification can be very useful, allowing hypotheses of anthropological interest within a behavioral-ecological-systems framework—as opposed to only a behavioral framework—to be formulated or tested. A broadening of both the processes and goals encompassed by intrasite spatial analysis beyond its traditional focus is possible, and has already been anticipated (e.g., Binford, 1983, chapter 6).

Events vs. processes. It is important to recognize, as Figure 1 shows, that using intrasite artifact distributions to estimate the states of variables that comprise a behavioral-environmental system does not require that specific behavioral *events* (activity episodes) or natural *events*, per se, be reconstructed. Inference need not proceed from spatial patterns to events to processes to system variable states, although it may. Rather, estimation of a behavioral or natural variable's state can be achieved more directly. Spatial patterns can be used to reconstruct formation processes themselves, directly, and these can serve as estimates of or can be used to infer estimates of the states of variables. That this is true can be argued both theoretically and by example.

From a theoretical standpoint, Binford (1981, p. 200) has emphasized that a cultural system is an open system, capturing and reorganizing matter and energy and relinquishing them through various cultural formation processes. Cultural formation processes are *components* of a cultural system that define its structural and dynamic properties. Those endproducts of cultural formation processes that indicate their past operation—various aspects of the organization of the archaeological record, such as intrasite artifact organization—thus *by definition* reflect the structure and dynamics of the cultural system. Similarly, natural formation processes are components of a local environmental system that define its organization properties. By definition, those effects of natural formation processes on intrasite artifact organization that indicate their past operation reflect the structure and dynamics of the natural environmental system.

Some examples of the use of intrasite distributional data to directly reconstruct cultural and natural formation processes, and the use of these as the states taken by variables within a behavioral-natural system or to infer such variable states, have briefly been alluded to, above. These can be clarified by focusing on less typically used extra-activity cultural formation processes and natural formation processes.

Among the variable states of a behavioral system that can be reconstructed in this manner are spatial and temporal pattern of regional mobility, degree of sedentism, and group size. Binford (1980, p. 9) has systematically linked the clarity of spatial structuring of use-areas within hunter-gatherer sites to the regional spatial pattern of their mobility (untethered residential, tethered residential, logistic) as determined by the grain of their natural environment (fine, patchy, coarse). For example, residential camps and extractive locations in some patchy environments, where the number of loci available for settlement and exploitation are limited, are likely to exhibit spatial patterns of artifacts that are considerably "blurred." This results from repeated reuse of the sites and spacing of activities in slightly different ways with each occupation. Ebert (1983) has extended Binford's framework so as to consider the organization of artifacts within "landscapes" (site and offsite areas as a continuum) as a function of various residential and logistic mobility options. Binford (1978) and Yellen (1974) have tied variation in the spatial configuration of hunter-gatherer camps to the season of their occupation, indicating temporal patterns of mobility. For example, Binford suggests that the more complex spatial patterning of winter camps than summer camps of Nunamiut Eskimo relates in part to the random loss of objects in the snow in winter sites, but not in summer sites. Finally, intrasite spatial patterning, as manifest in the degree to which refuse is deposited in formalized dumps as opposed to left within work areas, has been shown to be related to community population size (Schiffer, 1972, pp. 161-162) and degree of sedentism (Murray, 1980). As community population size increases, factors such as the need for unrestricted routes of access between principle work areas, sanitation, and scarcity of work space, place a premium on the discard of refuse in out-of-the-way places. Thus, a number of different variable states of a past behavioral system can be indicated by or inferred from extra-activity cultural formation processes that are directly reflected by different aspects of the spatial arrangement of artifacts within a site.

There are numerous examples of natural system variables, the states of which can be estimated through identification of natural formation processes directly from intrasite artifact distributional characteristics. These include various climatological variables; fluvial, aeolian, and other geomorphological variables; and vegetational variables. Butzer (1971, 1982) and Wood and Johnson (1978) describe these identification and estimation procedures in great detail.

Expansion of the scope of intrasite spatial analysis to include the reconstruction of extra-activity formation processes and natural formation processes in addition to activities provides several advantages.

Advantage 1. As mentioned above, it allows the researcher to investigate the structure and dynamics of both natural environmental and behavioral systems, not just the latter.

Advantage 2. It provides the archaeologist with a means for formulating or testing hypotheses about regional behavioral-environmental system organization with *intrasite* data that are *independent* of *regional* data. For example, hypotheses about mobility patterns can be tested with intrasite information on artifact arrangement as well as regional site distributional data. Thus, the archaeologist is placed in a better position for building and testing theory without circularity.

Advantage 3. Knowledge of the past occurrence of natural formation processes and extra-activity cultural formation processes within a site can give one an appreciation of the limitations of one's data. It can provide insight into those aspects of the data's structure that are relevant for making *behavioral* interpretations and those that are not (Schiffer, 1983).

This is especially true in regard to knowledge about natural formation processes. Natural formation processes do not always *reduce* patterning and increase entropy within the archaeological record (Ascher, 1968). They also can *produce* patterning which is not at all useful in reconstructing human behavior. The burrowing action of earthworms can produce novel arrangements of surficial debris (Ascher, 1968; Stein, 1983). Freeze-thaw cycles can produce "patterned ground" (surface stone aggregations in the shapes of rings, polygons, or stripes) or stone pavements. Expansion-contraction cycles in vertisols can form "linear gilgai" (Wood & Johnson, 1978). Water washing, wind, and soil creep can sort objects over space into different size, shape, and density classes (Shipman, 1981; Behrensmeyer & Hill, 1980; Gifford, 1980, 1981; Limbrey, 1975; Rick, 1976). The characteristic spatial patterns produced by these and other natural formation processes can be used to identify them within an assemblage, either visually or with the aid of quantification. At the very least, their approximate impact on the assemblage and their effect on its potential for behavioral reconstruction can then be assessed. In more favorable circumstances, their effects can be modeled and segregated from the data, leaving behind largely behaviorally significant variability to be studied (see Carr, 1982a, 1986 for appropriate quantitative techniques; also Villa, 1982).

Similarly, knowledge of the occurrence and effects of extra-activity cultural formation processes can be enlightening. For example, a researcher might come to an understanding that a site is a product of repeated, functionally similar, randomly overlaid occupations associated with a tethered mobility system, as evidenced by the ubiquitous distribution of most artifact types. This would suggest very strong limitations to intrasite spatial data for reconstructing community layout and organization.

In summary, the goals and processes encompassed by intrasite spatial analysis can be expanded to define a conceptual process involving minimally the four levels of abstraction and the three kinds of inferential pathways between levels shown in Figure 1. Whereas early studies of intrasite spatial patterning concentrated on reconstructing activities in order to document past lifeways or to monitor the organization and dynamics of past behavioral systems, current studies can be broader. They can involve the reconstruction of extra-activity cultural formation processes and natural formation processes as well as activities. And they can monitor both behavioral and natural environmental systems. This expansion of the scope of intrasite spatial analysis is advantageous in regard to the range of phenomena into which insight is afforded, the structure of archaeological reasoning, and the evaluation of data for their relevance.

It is necessary to qualify the above arguments. Although identification of formation processes through the spatial analysis of intrasite artifact patterns can be important, it should not be concluded that the proper position of such identification in the analytic process is only as the *outcome* of quantitative analysis. Some general knowledge about the formation processes that are responsible for a site is required if spatial analysis of its artifact distributions is to be relevant, accurate, and meaningful. This circumstance is addressed later (see pp. 316-328).

Evaluation of an Operational Goal of Intrasite Spatial Analysis

Current advances in understanding of the processes that generate archaeological records and their internal organization requires archaeologists to reassess not only the inferential goals of intrasite spatial analysis, but also its operational goals. Certain quantitative operations designed to search for certain kinds of spatial patterning among artifacts may or may not be concordant with the nature of artifact organization within sites. This section focuses on one operational goal: determining whether different artifact types are *arranged similarly or differently* over a site as a whole, that is, *globally*.

Whallon (1979, 1984) has stated that the search for global spatial patterns of coarrangement among artifact classes within sites is meaningless. He has implied that sitewide constructs such as tool kits, storage sets, etc., in the behavioral domain do not exist, or at least are impossible to reconstruct from archaeological remains. His new technique, unconstrained clustering, is designed explicitly to avoid the assessment of sitewide relationships between artifact types. It focuses on patterns of association or covariation of artifacts *within* clusters.

In discussing Whallon's position, I first would like to reiterate and expand on an argument that I have made previously (Carr, 1984). I then will qualify this argument and my previous conclusions.

The basis Whallon gives for his position is his correct observation of an erroneous assumption about formation processes that was implicit in early quantitative spatial analyses. Early analyses assumed that the *organization* of artifact types within the behavioral domain of past events was *transferred uniformly* into the archaeological domain, without variation over space. Thus, artifact types could be assumed to be organized in *one* manner across a site as a *whole*. Globally homogeneous structures—sets of artifact types showing spatially uniform patterns of coarrangement (e.g., covariation, association)—were sought. These structures were taken to indicate past activities and the organization of artifacts involved in them.

Current information on archaeological formation processes makes the assumption of spatially uniform transformation of artifact organization from the behavioral domain into the archaeological untenable. This position implies that *all* archaeological formation and disturbance processes responsible for a site's configuration were *spatially correlated* over the site as a whole (Carr, 1982a, 1986). In every site location where artifacts of a given type were manufactured, used, cached, or disposed of, the same processes of formation of deposits and post-depositional disturbance of them are presumed to have occurred to the same degree. For example, breakage rates, curation rates, degree of mining and recycling of artifacts, and rearrangement of artifacts by natural and agricultural disturbance processes are all assumed to have occurred in a uniform manner over the whole site. This assumption is not acceptable. Many formation and disturbance processes can occur in restricted portions of a site—different processes in different subareas.

The lack of spatially uniform transformation of artifact organization from the behavioral to the archaeological domain and the variability it introduces into spatial relationships in the archaeological domain does not necessarily imply, however, that such irrelevant variability cannot be isolated and *removed* from analysis statistically or overcome through the use of techniques *insensitive* to such forms of variation. It does not necessarily imply that global artifact organization pertaining to tool kits, storage sets, and related phenomena cannot be revealed (Carr 1982a, 1986, also below). Also, it does not necessarily imply that global organization of artifacts into such sets does not exist in the behavioral domain. These propositions remain to be demonstrated empirically.

Whallon (1984, pp. 251-258) gives some results of his analysis of the Mask site as empirical support of the proposition that global organization of artifacts into sets relevant to past behavior does not occur in most archaeological sites. He observes that at Mask, the same set of artifact types can show different patterns of covariation or association (positive, null, negative) over the site—that is, different forms of organization in different portions of it.

This datum, however, need not imply a lack of behaviorally relevant global structure. Variation over a site in patterns of local covariation or association of artifact types may indicate simply that correlation and association do not measure the strength of relationships between artifact types along scales that are pertinent to and concordant with the organization of tool kits, storage sets, etc.

The structure of any data set can be investigated from multiple angles using multiple techniques and different scales of measurement, implying different theoretical perspectives on what constitutes relevant data structure. This is a basic premise of exploratory data analysis (Tukey, 1977; Hartwig & Dearing, 1979). The lack of behaviorally relevant global organization that was found in the Mask data with correlation and association measures does not imply that relevant global organization does not exist in it relative to other techniques assuming other scales of measurement and implying other theoretical perspectives on the organizational nature for formation of archaeological records.

It can be argued that behaviorally relevant organization of artifact types into global sets reflecting tool kits, storage sets, refuse sets, etc., within sites often does occur. However, in this viewpoint, the nature of that organization is thought to vary among sites with the behavioral and environmental contexts of their formation, disturbance, and recovery. Moreover, the sets are thought in most circumstances—particularly those of hunter-gatherer sites such as Mask—to have a *polythetic* organization rather than a *monothetic* one, and to be *overlapping* rather than *nonoverlapping*. Under these conditions, correlation and simple association are not appropriate measures of the strength of relationship between types (Carr, 1984, below). They may not be capable of defining global sets of artifact types that accurately reflect tool kits, refuse sets, etc. Thus, from this perspective, Whallon's empirical results probably can be explained by an incompatibility between the analytic techniques he used to represent the Mask data set and those aspects of its structure relevant to tool kits and other sets. At minimum, no conclusions can be drawn as to whether artifacts exhibit global organization at Mask, and certainly no conclusions can be reached concerning whether they exhibit global organization within archaeological sites in general or within the behavioral domain in general.

Additionally, and more critical, the portion of the Mask data used by Whallon are insufficient to infer whether global structures such as archaeological tool kits, storage sets, etc., exist at the site. Each activity inferred by Whallon to have occurred at Mask is indicated primarily by *one* artifact type: rearmament by projectiles, wood working by wood scrap, butchering by large bones, final food processing and consumption by bone scrap, and multiple tasks by tools of unspecified function. Thus, the spatial variation in correlations between types observed at Mask do not document primarily the locally variable, *internal organization* of archaeological tool kits, refuse sets, etc. Rather, they document variable patterns of *spatial overlap* of activities and of the single artifact types representing them. They reflect relationships between artifact types in *different* artifact sets rather than *within* artifact sets. It is not possible with Whallon's selection of artifact types or in the way he has interpreted their meaning to conclude much about the degree of uniformity in the organization of archaeological "tool kits" over space.

The search for broad-scale patterning of artifact types within archaeological sites—in spite of the common difficulty of removing or overcoming a large percentage of the spatially differential effects of formation and disturbance processes—seems a reasonable goal, considering the probable existence of behavioral correlates for such patterns. Ethnography, ethnoarchaeology, and experimental approaches to the study of artifacts suggest that certain kinds of tools and debris do tend to be manufactured, used, curated, stored, and/or systematically disposed of together, constituting tool kits, manufacturing sets, cache sets, refuse sets, and other functional groups in the behavioral domain (see Carr, 1984, Table 1, for a long list of supporting references). Archaeologists need not give up the search for such sitewide entities. Rather, it is necessary to realize that 1) such sets—in both the behavioral and archaeological domains—can vary in structure from site to site, depending on environmental and behavioral contexts, and 2) the techniques used to search for them in any single case must be concordant with their particular structure and must remove or be insensitive to extraneous sources of variability. The various forms of polythetic association coefficients to be introduced later in this chapter are designed with these concerns in mind.

A qualification must be added to this argument. This pertains to the concepts of *pooled contradictory structures* and *subglobal components of artifact palimpsests*. Suppose two artifact types, A and B, sometimes are used together in the behavioral domain and deposited together on a site. At other times, A and B are systematically used in different activities and deposited separately. These two different relationships between A and B define different, contradictory artifact structures: one tool kit and depositional set in the first case, and two tool kits and depositional sets in the second case.

Contradictory artifact structures can be pooled within a site in two different ways. 1) They may be overlaid, one on top of the other, to greater or lesser degrees in various portions of the site. The result is what may be termed an artifact palimpsest (Carr, 1982a, 1986). 2) They may be segregated in different areas of a site.

If either of these conditions pertains, any attempt to define the degree of coarrangement among the two types using any coefficient of coarrangement applied to the *site as a whole* will give mixed results. The derived coefficient of coarrangement will measure the *average* strength of relationships among the two types considering *both* structures. It will also be affected by the relative frequency of the two structures. The coefficient will not accurately characterize the relationship between A and B for either structure. This is as true of polythetic measures of coarrangement as monothetic ones. It may be one unstated reason why Whallon finds meaningless the search for global patterns of coarrangement among artifact types within sites.

Nevertheless, useful results at a supralocal to sitewide scale of organization can often be obtained. To derive relevant estimates of the coarrangement of the two types at such scales, one must analyze the different structures separately and accept more than one estimate of the degree of coarrangement of the two types within the site. Separating the two structures for analysis can be achieved for either kind of pooling if the structures define clusters of different sizes and the artifacts of each type are fairly numerous. In this case, Fourier techniques can be used to resolve and isolate variation attributable to the two structures in the form of *subglobal components* of the artifact type distributions. Analysis of coarrangement then proceeds separately for the different structures using Fourier components within subglobal portions of the site (contiguously or noncontiguously distributed) rather than the original, undissected artifact type distributions. I have explained how to achieve such separation and analysis at length elsewhere (Carr 1982a, 1986).

In sum, previous discussions by Whallon (1979, 1984) and myself (1984) on searching for coarranged artifact classes within sites have been unclear in some respects. They have not taken into consideration the distinction between 1) *one* structure having a variable (e.g., polythetic) form of organization over a site (e.g., a polythetic depositional set), and 2) pooling of *multiple* different, contradictory structures. If this distinction is kept in mind and efforts are made to overcome both potential analytic problems, then it is clear that search for coarrangement among different artifact types can be meaningful, albeit sometimes subglobally rather than globally. The multiple polythetic coefficients of coarrangement that are designed in this chapter and the research designs using Fourier procedures that are specified in other papers (Carr, 1982a, 1986) are presented in this light.

Evaluation of Logical and Operational Frameworks for Intrasite Spatial Analysis

Several recent articles by Whallon (1979, 1984), Carr (1984), and Schiffer (1983) have discussed or implied stepwise approaches to intrasite spatial analysis that differ fundamentally in ways that can influence analytic results. These differences include 1) the degree to which it is necessary to *identify* the formation processes responsible for the study area (a site or portion of it) and to assess their impact on the organization of artifacts within it *prior* to quantitative analysis, rather than as the outcome of it; 2) the degree to which the search for patterning in artifact scatters should proceed *deductively*, in light of such knowledge, rather than *inductively*; and 3) the extent to which *multiple, generalized* analytic techniques should be used to search for spatial patterning in any given study area.

The differences among the researchers are of degree rather than kind. Each would probably acknowledge the usefulness of assessing formation processes before spatial analysis and through the outcome of such analyses; of using one's insight into the origin and organization of artifact distributions within a study area to design analyses congruent with them; and of viewing the data from multiple analytic perspectives that best concord with the data's structure. However, the researchers do have different tendencies, the consequences of the extremes of which should be recognized.

Also, the differences between the researchers' approaches to be discussed here pertain to the logic of analytic operation at only the lowest levels of inference within the scientific process—the manner in which recognition of patterns and assessment of their relevance should proceed. The differences do not concern their entire frameworks for scientific thought. All the researchers hold to a model of science having higher-level deductive and inductive elements.

Finally, the differences in inductive and deductive logic of concern, here, pertain to the manner of *routine application* of technique to data, rather than the logical process by which technique is *developed initially*.

An Approach Tending to Be Largely Inductive

The first approach to pattern recognition and evaluation, discussed by Whallon (1984), has the following characteristics:

1) Unnecessary preanalytic evaluation of formation processes and form of artifact organization. Identification of the formation processes responsible for a study area, evaluation of their impact on the organization of artifact distributions within it, and characterization of the relevant relational structure[1] of the data at hand—all prior to spatial analysis—are not seen as critical operations. Whallon recognizes that activities and other cultural formation processes within a single site or a portion of it can produce use-areas having extremely variable characteristics, and that consequently, spatial relationships among artifact types may change from locale to locale. He also notes that these variable products of a cultural system can be disturbed and made even more variable over space by post-depositional processes. However, to obtain an "accurate" analysis and representation of such variable data, Whallon does not advise a familiar statistical approach involving, first, determining the relevant structure of the data at hand, and then, choosing a particular technique of analysis concordant in its assumptions with the data's relevant structure. He does not suggest that the *specific formation processes* responsible for the study area and the *peculiar relevant form of organization* of artifact distributions within it be reconstructed prior to analysis and that technique be chosen accordingly. Rather, he encourages: (a) the development of new techniques that make as few as possible constraining assumptions about those characteristics of use-areas and artifact type relationships that tend to be variable *in general* over the archaeological record, and (b) the *general* application of such approaches.

Whallon's philosophy is evidenced in two ways. First, his technique of "unconstrained clustering" is designed for this purpose. It is said to assume only the constancy of proportions of artifacts within use-areas and is recommended for general use in place of more assuming methods. Second, in his example analysis using unconstrained clustering, he does not reconstruct the formation processses responsible for the site that is analyzed nor the nature of organization of its artifact distributions, even in sketch, prior to analysis and choice of technique. Rather, the nature of the formation processes peculiar to the site is one of the conclusions of the analysis (Whallon, 1984, p. 277). This may result partially from the experimental nature of the study, which focuses on technique development instead of total analytical design, though this is not made clear.

2) Use of multiple unassuming techniques. Whallon suggests (personal communication, 1983) that *multiple*, generalized pattern-searching techniques, each making equally few but different assumptions about the relevant form of organization of artifact distributions, should be applied to intrasite data. This should be done in order to determine what distortions of the data may occur in any given representation of them, as a result of the limiting assumptions of the techniques used to display them. A more complete and true representation of the data's relevant structure should then be assembled logically (rather than quantitatively) from the multiple representations. Whallon does not suggest that the researcher identify the formation processes responsible for a given study area, then postulate the particular nature of that aspect of its artifact organization that is relevant to the researcher's behavioral or environmental interests, and finally choose *one* or a few techniques most concordant with that specific relevant form of organization in order to represent the data.

3) Inductive pattern recognition. From both 1) and 2) above, it is clear that Whallon favors a more inductive approach to pattern-searching, involving multiple representations of the data from which patterns thought relevant are *generalized.* This stands in contrast to a more deductive approach. A deductive approach would involve identifying or postulating the formation processes responsible for a study area, deducing from those processes the relevant form of organization of artifacts within it, deducing from that organization the analytic technique(s) most appropriate for its analysis, and thus the *specification* of relevant artifact patterns.

In line with Whallon's more inductive approach, we find that unconstrained clustering "is hardly more than an elaborate approach to a descriptive summary or *display* of the data, or a series of such summaries and displays" (Whallon, 1984, p. 275). The precise borders of use-areas are not specified by the technique, but rather, are left for the researcher to generalize from one or more representations of the data.

The operational framework for spatial analysis that Whallon supports appears to be an expression of a more general philosophy and approach to analysis that Whallon references: *exploratory data analysis* (Tukey, 1977; Hartwig & Dearing, 1979). Exploratory data analysis (EDA) is an inductive approach to pattern recognition attributable to Tukey (1962, 1977, 1979). Unlike the statistical approach, which involves deductive testing of hypotheses and seeks to determine whether a particular expectable structure (test implication) occurs within the data set, EDA asks the question, "What *unanticipated* structures or relationships occur within the data, regardless of expectation?" (Tukey & Wilk, 1970, p. 371; Hartwig & Dearing, 1979, pp. 9-10). It is "exploratory" rather than "confirmatory": it has as its goal the searching for patterns that suggest new ideas and problem areas, leading to hypothesis formation rather than hypothesis testing (Tukey, 1979, p. 122; 1980, pp. 23-24; Hartwig & Dearing, 1979, p. 78).

Achievement of this goal of EDA is facilitated in three ways. First, analytic "flexibility" is stressed, involving the use of multiple techniques and reexpression of the data on various measurement scales (Tukey, 1980, p. 24; Hartwig & Dearing, 1979, p. 10). Multiple mathematical models are used to investigate the data from multiple perspectives rather than using data to evaluate models (Tukey & Wilk, 1970, pp. 376, 386). The various representations of the data created through the use of alternative techniques and models are then to be searched for patterning with a mind open to new ideas and skeptical of single interpretations (Tukey, 1970, p. 372; Hartwig & Dearing, 1979, p. 9). Second, graphic representation and visual display of the data is stressed (Tukey, 1980, p. 24). Finally, alternative representations of a data set are evaluated as more or less optimal based on the parsimony of the techniques that generated them and the simplicity (e.g., normality, linearity, smoothness) of the patterns that they reveal. This approach facilitates hypothesis generation (Tukey & Wilk, 1970, pp. 375-376, 378, 385). Correspondence between the assumptions of techniques and the relevant structure of data, as posited by a prior guiding hypotheses, is downplayed.

Clearly, many aspects of Whallon's approach to searching for patterning in intrasite spatial data correspond to characteristics of the more general philosophy of EDA and vice versa. We must ask whether such an approach, in its fullest expression, is generally appropriate to the analysis of intrasite spatial data.

The stress placed in EDA on viewing the data from multiple perspectives with least constraint, and the open mindedness it fosters, clearly is valuable in facilitating scientific progress and escaping the tyranny of theory and paradigm (Clarke, 1972, p. 8; Kuhn, 1970). This approach should be a part of analysis to the extent that the relevant structure of spatial data is represented in an unbiased and accurate manner.

Nevertheless, there are limits to the usefulness of a largely inductive pattern recognition approach like EDA in the context of intrasite spatial analysis, and in the analysis of complex data in general (see Carr, chapter 2). These are as follows:

Limitation 1. From a general perspective, given the alternative representations of a data set that are generated within an EDA approach yet the downplaying of a priori hypotheses in guiding analysis, it may not be clear which representation(s) of the data are truest to the relevant aspects of its structure and its manner of generation, and thus, can be accepted. Suppose that multiple representations of a data set are displayed by several methods, each making equally minimal assumptions about the data's structure. Certain strong aspects of the data's structure may be apparent from commonalities among all the representations. However, where differences between the representations occur, on what basis does one accept one expression of the data over another in filling out a characterization of the data? Tukey (1970, pp. 378, 385) suggests accepting that structure which is mathematically most simple. However, reality often is complex, and this criterion does not necessarily lead to relevance or interpretability. Whallon does not address this problem.

If one considers that the differences between the representations of a data set may arise from differences in the degrees to which the several techniques defining them make assumptions that are congruent with the relevant structure of the data, and that some representations may be more accurate displays of the data's relevant structure than are others, then two things become apparent. (a) Appropriate choice among alternatives is critical. (b) One cannot make an appropriate choice between alternatives without reference to knowledge about the relative degree to which the assumptions made by the techniques probably concord with the data's relevant structure. This, in turn, requires some minimal, *general knowledge*, in the form of guiding hypotheses, about the actual or probable nature of the relevant structure of the data in hand. By general knowledge I mean such things as whether phenomena of interest manifest themselves as nonoverlapping or overlapping relationships among observations, or again, whether they manifest themselves in the distributions of or relationships between ratio, interval, ordinal, nominal, or polythetic-scale measures. Such information stands in contrast to *specific knowledge* about particular relationships among particular observations and variables. General knowledge can be obtained inductively or deductively from information on the context of the data, its mode of generation, and/or theoretical expectation (see pp. 324-325; also Carr, chapter 2). Thus, a strictly inductive approach to pattern recognition, divorced from general knowledge in the form of guiding hypotheses about relevant structure, may prove impossible.

This general limitation to inductive pattern recognition seems characteristic of its specific application to intrasite spatial analysis. The use of this operational framework in intrasite spatial analysis, as Whallon tends to favor (though not his technique of unconstrained clustering) does not seem effective. In particular, relevant relationships between artifact types within sites may be of many different kinds (e.g., monothetic vs. polythetic, overlapping vs. nonoverlapping, covariational vs. associational, etc.; see below), depending on the formation processes responsible for them. In order to choose the one or few representation(s) of an intrasite data set that are most likely true to the relevant aspects of its structure and to justify that choice explicitly, it is necessary that one have, prior to analysis, general knowledge—guiding hypotheses—about (a) the nature of the formation processes responsible for that particular study area, (b) the nature of the relevant organization of artifacts within it, and thus (c) the relative degrees of concordance likely between relevant aspects of the data and the several techniques used to generate representations of it. How such insight can be gained is discussed below (see pp. 324-328).

Limitation 2. This limitation is closely related to the first. Without reference to some prior knowledge about the relevant structure of the data in hand, an inductive framework like EDA cannot use the *strongest criterion* to judge the appropriateness of alternative techniques in representing a data set: the relative degree of concordance of the techniques to the data's relevant structure. Less powerful criteria of evaluation must be used. These amount to three. Tukey suggests that the most appropriate methods are those that are most *simple* in operation or that produce results having the most *simple* mathematical structure (Tukey, 1970, pp. 378, 385). Whallon, in his similar framework, suggests the appropriateness of those techniques that make the *fewest* assumptions about the nature of the data's relevant structure.

None of these criteria for evaluating alternative techniques, alone or together, are sufficient to ensure the accuracy of analytic results.

(a) Simplicity of the algorithm says nothing about whether the algorithm violates the data's relevant structure.

(b) Simplicity of results is not a sound basis for judgement, given the complex patterning commonly found in archaeological records. Polythetic, overlapping depositional set organization, palimpsest structure to artifact distributions, and hierarchical organization of spatial relations among artifact types and use-areas are examples of such complexity (Carr, 1984). These result from equally complex formation processes, often spatially disuniform and overlaid.

(c) Methods making the *fewest* assumptions about the structure of a data set need not be the least *constraining*, if those particular assumptions violate the specific relevant structure of the data under study while assumptions of the alternative techniques do not. Under some circumstances, even a very assuming technique may be most appropriate. For example, use of correlation and factor analysis to define archaeological tool kits implies many restrictive assumptions about the nature of organization of artifact types within tool kits in the behavioral domain, artifact organization within corresponding depositional sets in the archaeological domain, and the formation processes responsible for the transformation of organization between the two domains. These assumptions include the monothetic, nonoverlapping organization of tool kits in both the behavioral and archaeological domains; an expedient technology; extended use of activity areas; minimal post-depositional disturbance; etc. (see Carr, 1984 for a further discussion). Tool types are assessed as coarranged or not, and members of the same depositional set or not, compared to very restrictive standards of organization. Nevertheless, this methodology is appropriate when such conditions are approximately the case, as in Schiffer's simulation (1975) and application (1976) of it; and it is *more* appropriate under these circumstances than other techniques would be which assess the degree of coarrangement of types against less restrictive standards of organization (e.g., association analysis). In this case, less assuming techniques could judge some types to be coarranged (members of the same depositional set) when they actually are not. Thus, *a technique cannot be judged as more or less appropriate on its own basis, according to the number and restrictiveness of the assumptions it makes. It can be judged for its appropriateness, in the strictest sense, only in the degree to which its assumptions concord with the relevant structure of the particular data to which it is to be applied.*

Limitation 3. A final limitation to an inductive pattern-searching framework that does not use prior information and hypotheses about the nature of the data to be analyzed is that only the data *as given*, or as reexpressed in *standard* ways, can be considered and manipulated. Likewise, patterns found within the data must be taken at face value. The possibility of *systematic* bias or distortion of the data and its patterns in certain uniform directions, or of the data representing a meaningless though patterned *composite* of multiple, unique patterns produced by diverse processes (i.e., a palimpsest; Carr, 1982) cannot be evaluated.

This general limitation of an inductive pattern recognition framework is especially true when the framework is applied to the study of intrasite patterning and a priori knowledge about formation processes is not used. An archaeological record is the product of multiple cultural formation processes. The effects of these are often spatially *overlaid* but not necessarily spatially *correlated*, resulting in a complex arrangement of artifacts (a palimpsest) that is not meaningful as a whole, as given. Also, the record can be distorted systematically in some manner by post-depositional disturbance processes (e.g., down-hill creep and elongation of artifact clusters). Without some prior knowledge and assessment of the nature of the formation processes responsible for the specific artifact arrangement under study, it is not possible to evaluate the degree to which the data represent a complex palimpsest or are systematically biased; nor is it possible to dissect the palimpsest into meaningful components for separate study or to correct for such bias, if this is the case. A strictly inductive pattern-searching approach to intrasite spatial analysis can yield various representations of patterns only *as expressed* within the data, and these patterns need not be relevant to understanding past behaviors or environmental conditions.

An Approach Tending to Be Largely Deductive

The second approach to pattern recognition and evaluation in intrasite spatial analysis is one implied by Carr (1984). It has the following characteristics:

1) Primarily deductive pattern recognition. The approach stresses the deductive selection of the analytic technique used to reveal patterning. A single model of archaeological organization, positing certain characteristics of depositional areas and depositional sets (e.g., hierarchically arranged depositional areas, areas of variable shape, globally polythetic and overlapping depositional sets) is presented as the most common form of archaeological organization relevant to behavioral reconstruction. This model is based on current understanding of site formation processes that has been derived from ethnoarchaeological and experimental archaeological studies. Various spatial analytic techniques available for archaeological application are then characterized, by deduction, as more or less constraining in general in their assumptions, compared to the one form of relevant organization.

It is then recommended that in most cases, the one or very few techniques having assumptions concordant with the modeled form of organization be applied to the study area at hand. Although Carr recognizes that it is preferable to choose analytic technique in relation to general knowledge about the actual or probable organization of the particular study area so as to maximize analytic concordance, he also argues that in many cases, this specific insight is not available. Thus, the researcher often must choose technique primarily deductively, using understanding of the organizational nature of archaeological records in general. The results that are derived in these instances are to be taken as the most behaviorally relevant representation of artifact distributional patterning that is possible for the area under current knowledge limitations.

2) Downplayed preanalytic evaluation of formation processes and form of artifact organization. As a consequence of the stress placed on deduction, the identification of formation processes responsible for any *particular* study area, evaluation of their impact on the organization of artifact distributions within it, and characterization of the relevant structure of the data at hand, are not emphasized. Techniques are assessed for the appropriateness of their assumptions primarily in relation to a general model of relevant organization rather than site-specific relevant organization.

3) Use of a few concordant techniques. It is suggested that intrasite analysis proceed with one or a very few specific techniques—those having assumptions most concordant with the study area's relevant organization, as expected from the general model of organization, or sometimes as known empirically. A unique solution which represents the data most accurately is sought. It is not recommended that the data be searched inductively with multiple techniques for multiple configurations.

Limitation. The more deductive approach to pattern recognition taken by Carr (1984) is just as tenuous as the inductive one discussed previously. Its primary drawback is that a technique's appropriateness is most often assessed relative to a *general model* of relevant archaeological organization, rather than the relevant organization of the *specific data* to be analyzed. To the extent that the data vary in structure from that proposed in the general model, a technique can be more appropriate or less appropriate for application to the data than its general assessment implies. Once again, a technique can be judged for the appropriateness of its assumptions, in the strictest sense, only in the degree to which its assumptions concord with the relevant structure of the particular data to which it is to be applied. Comparison of the assumptions of a technique to a general model of data structure—even if the model embodies the most commonly found kind of structure—will not do.

In summary, although the logical and operational frameworks used by Whallon and Carr differ in whether pattern recognition proceeds inductively or deductively, and in the degree to which multiple generalized techniques are employed, both frameworks share a critical flaw. They do not encourage the researcher to specify, prior to analysis, the nature of relevant organization of the particular archaeological record under investigation, and to choose analytic technique in relation to it. Although both frameworks express a concern for the tailoring of technique to relevant data structure, this tailoring is done at a *general level* that does not allow fine tuning of the relationship for specific data sets. Whallon proposes a *general technique* thought applicable to a diversity of intrasite data structures; Carr proposes a *general data structure* common to archaeological sites and suggests methods congruent with that structure.

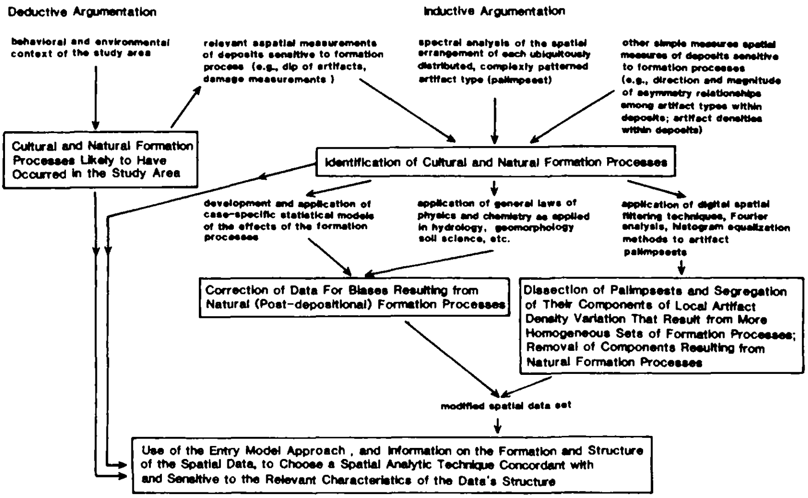
In rightly trying to systematize methodology for the analysis of intrasite artifact distributions, both researchers have unfortunately downplayed the importance of evaluating the relationship between technique and data at the case-specific level. This is manifested in the lack of stress that either researcher places on identifying, prior to analysis, the formation processes responsible for the specific nature of the relevant organization of a study area.

A Pattern-Searching Framework Combining Inductive and Deductive Approaches: The Use of Entry Models and Parallel Data Sets

To overcome the problems associated with each of the two analytic frameworks previously discussed, and particularly to encourage evaluation of the relationship between technique and data at the case-specific level, an alternative framework can be used. This pattern recognition approach combines inductive and deductive relationships. It also emphasizes the importance of identifying the formation processes responsible for a study area's structure, and the specification of the general nature of that structure prior to analysis. The approach encompasses and expands upon a position on intrasite analysis taken by Schiffer (1983), and involves the use of entry models and parallel data sets, as discussed in chapter 2 by Carr. The steps of such a framework are summarized in Figure 2 and discussed as follows:

1) The formation processes—cultural and natural—responsible for a study area should be identified and assessed for their effects as much as possible. Identification of formation processes as a first step in intrasite analysis is Schiffer's primary contention. This can be done in an inductive manner using at least two approaches *not* involving the techniques and data to be used ultmately in defining depositional areas and depositional sets. (To not do so would be to invite circular reasoning into analysis). (a) A variety of *aspatial* measurements that are collected from multiple locales and deposits within a

Fig. 13.2. A pattern recognition framework that 1) combines inductive and deductive elements, 2) stresses "up front" identification of formation processes, and 3) uses the entry model approach to choosing an appropriate analytic technique. It is assumed in this schema that behavioral rather than natural formation processes are of interest.



study area expressly for the purpose of identifying formation processes can be evoked. Such data might include frequency distributions of the size, specific density, orientation, or dip of artifacts or natural inclusions within various locales of the area; information on the use-lives, damage, and conjoinability of artifacts and their fragments within different deposits; and a large variety of sedimentological, geochemical, and ecological measures. Data of these kinds would constitute a simple, *parallel data set*, giving the researcher insight into relevant and irrelevant aspects of the structure of the *complex* artifact distribution data set of interest (to use the terminology presented in chapter 2). Schiffer (1983) does a very thorough job of inventorying and referencing discussions on these kinds of data and suggests their potential usefulness in reconstructing formation processes. (b) Distributions of artifact types appearing to be complex palimpsests can be investigated inductively for the possible occurrence of more meaningful components of local artifact density variation within them, using the technique of spectral analysis (Jenkins & Watt, 1968; Brillinger, 1975, chapter 5; Ontes & Enochson 1978, chapter 8). This method allows the predominant spatial scales and orientations of clusters of artifacts within such a distribution to be determined in spite of possibly complex patterns of overlap and post-depositional smearing of them. It can also be used to assess the spatial scale and orientation of smearing processes. Such information on the several scales and orientations of operation of cultural formation processes is invaluable in dissecting artifact palimpsests into more meaningful components, each due to a more homogeneous set of formation processes. Carr (1982a, 1986) summarizes the procedures by which this archaeological application can be made.

2) Using the knowledge gained on the nature and effects of specific formation processes on the structure of the artifact distributional data on hand, each artifact type distribution should be corrected as much as possible for post-depositional distortions (Schiffer, 1983). Where necessary, the distribution should be dissected into components, each representing a more homogeneous set of cultural or natural formation processes. If cultural formation processes are of interest, the components that are attributable to them can be analyzed separately in later steps of spatial analysis, free of interfering effects from each other and also from natural sources of distortion. If natural formation processes are of interest, their components can likewise be segregated and focused upon.

For the sake of explanation, let us consider isolating and analyzing behaviorally relevant aspects of the artifact distributional data. As in step 1, two means for achieving these ends are possible. (a) Schiffer (1983, pp. 677, 694) holds that because natural formation processes exhibit regularities, it is possible to build statistical or quantitative models of their effects on the particular deposits at hand. The models may be used to correct archaeological measurements of the deposits for biases resulting from the processes. A clear example of this approach is Rowlett and Robbin's (1982) quantitative method for reconstructing the original frequencies of artifacts deposited in strata prior to their post-depositional migration. Established physical and chemical laws also can be used to correct for biases. Application of the laws of movement of sedimentary particles within flowing water to water-rearranged artifact distributions is an example (Shackley, 1978; Gifford, 1980, 1981). (b) The methods of digital spatial filtering and Fourier analysis (Davis, 1973; Holloway, 1958; Robinson, 1970; Zurflueh, 1967; Gonzalez & Winz, 1977; Castleman, 1979) can be used to dissect each complex artifact distribution into component distributions of more homogeneous cause, allowing the isolation of behaviorally significant artifact density variations. This approach assumes that different kinds of activities, other cultural formation processes, and natural ones operate over areas of different spatial dimensions. Mathematical filters are designed to extract artifact density variations of particular scales or "frequencies" thought significant, based on previous spectral analysis of the data. The technique called histogram equalization (Gonzalez & Winz, 1977) can be used favorably to enhance the separation process. Carr (1982a, 1986). details a number of alternative concatenations of procedures for breaking apart an artifact palimpsest. The appropriate analytic design depends on the degree of density contrast between artifact clusters of the same or different sizes, the crispness of their borders, and whether high frequency noise due to unsystematic artifact recovery, unsystematic curation or recycling, or other causes is present in the data.

3) The spatial data set, which has been reduced to a group of behaviorally relevant component artifact density distributions and/or corrected for post-depositional disturbances, should be subsumed under one or a few alternative a priori models—*entry models*—that most likely represent the data's general relevant structure, that reflect its manner of formation, and that link it to an appropriate technique of analysis. Each entry model used for this purpose should involve three elements. (a) First is *a general organizational model of fundamental mathematical characteristics of artifact patterning.* Such characteristics might be whether artifact types occurring in the same depositional sets exhibit spatial asymmetry relations (Pielou, 1964); whether the direction of asymmetry is globally constant or reverses locally; whether the sets are likely monothetic or polythetic, overlapping or nonoverlapping; whether artifact clusters spatially overlap or not; etc. (b) The second element of an entry model is a list of the *formation processes* that might lead to the characteristics in the organizational model. (c) Finally, an entry model should specify the range of mathematical techniques having assumptions that are concordant with the organizational model's structure. By subsuming the spatial data set under one or a limited number of such entry models, linkage of the data (through the listed formation processes and the organizational model) to appropriate technique(s) for spatial analysis, and choice of such technique(s), is facilitated. Also, from a previous perspective (p. 319), the appropriate analytic technique(s) are specified using "general knowledge" of the relevant structure of the particular data in hand.

The subsumption of a data set under one or more entry models can be achieved by matching the formation processes responsible for the study area with those specified in the models. The formation processes which are enumerated as "responsible for the study area" and used for this purpose can be ones that have been documented *inductively* with information collected in Step 1, above. They also can be a set of hypothesized formation processes that are thought *likely* to have occurred in the study area and that have been suggested *deductively*. Deductive specification of such processes involves observing the general behavioral and environmental contexts of the site (e.g., approximate degree of regional mobility of the site occupants; the order-magnitude of site population; distance of the site from lithic resources as determinants of curation rates; geomorphic depositional setting), and then suggesting on the basis of theory or regional empirical generalizations whether particular formation processes operated on it (Schiffer, 1983, p. 692).

4) On the basis of the subsumption of the particular spatial data set under one or more general entry models (i.e., general knowledge of the data's relevant structure), one or more techniques most likely appropriate for analysis should be chosen (deduction). Where it is unclear which of several organizational models is most representative of the data and several techniques are used to analyze the data, a diversity of results may be generated. The alternative behaviors or other formation processes suggested by the alternative relationships in these solutions can be considered alternative hypotheses. They should be tested with independent information not used in associating the spatial data with the organizational models or techniques. Examples of such information would be use-wear data and conjoinable-pieces data, giving insight into the life histories, joint usage, and depositional patterns of artifact types (Van Noten et al., 1978; Cahen & Keeley, 1980; Villa, 1982).

Advantages of the entry-model approach. Using this pattern recognition framework, which combines both inductive and deductive elements, frees the researcher from the drawbacks of a strictly inductive or deductive search framework that were discussed preivously. Steps 1 and 2, involving correcting and dissecting the spatial data, ensure that the spatial data to be analyzed are both behaviorally significant and homogeneous in cause, as opposed to being distorted by post-depositional processes or a meaningless composite of patterning. In other words, the steps ensure that the data brought forward for analysis have a relevant relational and subset structure (see Note 1). Steps 3 and 4, concerned with positing those structural characteristics of the modified data that should or should not be assumed by the technique(s) to be used in analyzing the data, ensure that the method(s) chosen for analysis are those most concordant with the *specific* data in hand rather than those making the *least assumptions* or those *most commonly appropriate*, whether concordant or not with the specific case. All of the objectives of these steps must be realized if spatial data are to be represented in a meaningful way. Finally, by placing spatial analysis in the context of an understanding of the formation processes responsible for the data, it is possible to test alternative results for the likelihood of their accuracy in characterizing the data by evaluating whether the formation processes did, in fact, occur. This is not possible in the inductive approach described previously.

The keystone to this framework for pattern recognition is the premise long held by Schiffer (1972) and realized in a less systematic way by many archaeologists. This is that the *first order of business* of an archaeologist must be identification of the processes that generated the deposits to be studied, assessment of their relevance to the problem of interest, and correction for their inadequacies when possible. As he (1983, p. 697) has so strongly stated:

> The importance of identifying formation processes before behavioral or environmental inferences are offered can not be overemphasized. In far too many cases, the evidence used by an archaeologist owes many of its properties, not to the phenomena of interest, but to (other, irrelevant) formation processes. . . . If the latter are identified 'up-front', using the most sensitive lines of evidence, then the investigator will be able to establish which deposits are comparable and choose the most appropriate analytic strategies. On such a foundation are built credible inferences.

MODELS OF ORGANIZATION OF DEPOSITIONAL SETS AND ACTIVITY SETS

Having set forth a philosophy on how intrasite spatial analysis should proceed, a major task remains in developing alternative mathematical models of archaeological organization. These are essential components of the desired entry models that will facilitate the linkage of data having given structures and origins to techniques appropriate for their analysis. In this section, a first step is made in this direction. The organizational models to be discussed explore only two fundamental dimensions of artifact spatial organization, both concerned with only the *coarrangement* of artifact types. The models are useful in linking data to only those techniques that define sets of coarranged types. No attempt is made to model the alternative characteristics of use-areas and the conditions under which various methods are appropriate for delimiting them. A start in this direction, however, is provided in the first and last papers (Carr, 1984, 1986) of the series of which this one is a part

Basic Terminology

The models to be developed are concerned with linking fundamental organizational characteristics of archaeological deposits to formation processes and antecedent organization. Consequently, it is necessary to distinguish structures in the archaeological present from those from which they were derived in the behavioral past when referring to relationships among artifact types. Current terminology in archaeological literature does not permit this distinction, however. The terms "activity set" and "tool kit" are used to refer to structures in both domains: on the one hand, to those artifact types that were repeatedly used or produced together by the occupants of a site during the behavioral past; and on the other hand, to those artifact types that repeatedly occur together in the archaeological record when it is excavated.

To avoid ambiguities, these two different phenomena will be given separate terms here. The set of tool types that were used repeatedly in the past to perform a particular task and the debris which resulted from that task are called an *activity set.* In contrast, the tool and debris types that repeatedly are found together in the archaeological record today are termed, in the broadest sense (see below), *depositional sets.* Activity sets may be said to belong to a *behavioral domain* whereas depositional sets belong to an *archaeological domain.*

Depositional sets may be more diverse than activity sets in the processes responsible for their structure and content, and thus are more variable in meaning. In the behavioral domain, the tools and debris that are associated are those actually produced and/or used together. In the archaeological domain, the tools and debris that are found together could represent a number of behavioral phenomena. They might represent primary refuse bearing all the tools and debris produced and used together in one kind of task by the previous occupants of the site. Or they might include only a portion of those artifacts, if some were saved for use in other activities at a later time. An association of artifacts also could represent a cache—a special form of primary refuse containing items stored together for later use together in one or a diversity of tasks. Another possible kind of aggregation is tools and debris from many activities thrown away together in a formalized dumping location. Even more diverse, an aggregation of artifacts might not reflect past human behavioral processes at all, but rather, post-depositional processes of natural origin or contemporary human origin, such as fluvial transport or contemporary farming.

To refer in a precise way to the multiple kinds of depositional sets with different meanings, at the same time distinguishing them from activity sets, a hierarchy of terms can be used. At the most general level, the term *depositional set* can be used to describe associations of artifact types, without specifying the processes by which the associations were generated. Behavioral, geological, biological, or agricultural phenomena might be responsible for them. If natural or agricultural disturbances do not appear to have generated the associations and past behavioral processes appear responsible, the more specific term *anthropic depositional set* can be used for the associations. This implies that the associated types were repeatedly manufactured, used, stored, or disposed of together, but not specifying which of these. Finally, at the most specific level of designation, repeatedly associating artifact types might be *archaeological manufacturing sets, archaeological butchering sets, archaeological wood working sets, archaeological storage sets, archaeological refuse sets*, etc.

Mathematical Concepts and Dimensions of Organization

It is possible to view the structure of activity sets and depositional sets, and the formation and disturbance processes linking them, in mathematical, set-theoretic terms. A depositional set can be envisioned as a mathematical set, the organization of which is the end-product of structural transformations (archaeological formation and disturbance processes) operating on a previously structured set (activity sets organized by human behavior). In set theoretic terms, activity sets in the behavioral *domain* are *mapped* into depositional sets in an archaeological domain (or more precisely, *range*) through the operation of various *mapping relations* (Ammerman & Feldman, 1974).

Such an analogy of archaeological structures and processes to mathematical ones is useful. Through it, two fundamental dimensions of organization of artifacts within both the archaeological and behavioral domains are revealed. Importantly, these dimensions can be used not only to characterize the organization of particular configurations of artifact types in specific behavioral contexts or archaeological deposits, but also to determine the appropriateness of applying various spatial techniques to reveal such organization. Moreover, the effects of various formation and disturbance processes on artifact organization can be expressed vividly and succintly in terms of the two dimensions. In brief, the analogy provides a productive mechanism for developing entry models of archaeological organization capable of linking specific data structures, formation processes, and techniques, as desired.

The two dimensions of organization identified are 1) a *nonoverlapping-overlapping organizational continuum* and 2) a *monothetic-polythetic organizational continuum.* These may be explained by reference to some basic concepts of set theory.

In set theory, an organization of entities can be described by using four basic concepts: 1) a *set*—a group of entities, 2) *members* or *elements of a set*—the entities that are grouped together, 3) *attributes*—the character states that the entities possess, and 4) the *list of attributes* that the entities in a set must share in part or in full to belong to it. To apply these concepts to the behavioral and archaeological domains for the purposes of describing the organization of activity sets and depositional sets and the organizational transformations linking them, untraditional referents are required. It is necessary to focus on sets of *events* and sets of *deposits* generated by them, rather than sets of artifact types (activity sets, depositional sets, tool kits). Suppose a group of past events at a site can be classified into several kinds according to the functional types of artifacts they involved. The several *events* (entities) that are of one kind comprise a *set*: they always or often entailed certain common artifact types (attributes). The several *artifact types* that were used in common comprise a *list of attributes* defining the set, or what has been termed above, an "activity set." Similarly, suppose that the archaeological *deposits* within a site can be classified into several kinds according to the functional types of artifacts they contain. The several deposits (entities) that are of one kind comprise a *set*; they always or often contain certain artifact types (attributes). The several *artifact types* held in common or tending to be held in common by the deposits comprise a *list of attributes*, or what has been termed above a "depositional set."

It is unfortunate that the term, activity set, occurs in archaeological literature, because in set-theoretic terms and within the framework presented here, it is a *list of attributes* required for membership in a set (of events) rather than a set, itself. Similarly, a depositional set is not a mathematical set, but rather a list of attributes required for membership in a set (of deposits). Since the term, activity set, is cemented in archaeological literature and depositional sets are analogous to them, I will continue to use these archaeological terms along with the mathematical.

The organization of sets, and by extension, the organization of lists of attributes that define their members, can be characterized as overlapping or nonoverlapping in nature, and monothetic or polythetic in nature. Although these concepts are introduced most easily as categorical descriptions of organization, it will be shown that they can be extended to refer to continuous dimensions of organization—a framework more useful for our purposes.

Nonoverlapping vs. overlapping sets. Different sets are said to be overlapping when their members share some of the character states required of them (partially or completely) for admittance into their respective sets. Different sets are said to be nonoverlapping when the members do not have in common any of the character states required of them for admittance to their sets (Jardine & Sibson, 1968; Sneath & Sokal, 1973, pp. 207-208). In the behavioral domain, two different functional categories of events—different sets of events—which are defined by the artifact types used in them, would be considered overlapping sets if some of the artifact types defining the sets were shared by them. The sets of events would be nonoverlapping if none of the artifact types defining them were shared by them. In the archaeological domain, two different functional classes of archaeological deposits—two different sets of deposits—would be considered overlapping if some of the artifact types defining the sets were the same. The different sets of deposits would be non-overlapping if none of the artifact types defining them were the same (Table 1).

Similarly, by extension, different lists of attributes required partially or completely of the members of different sets can be termed overlapping if some of the attributes in the lists are the same. They can be termed nonoverlapping if none of the attributes in the lists are the same. Two activity "sets" (two different lists of artifact types that always or often were entailed in the events falling in two different sets) would be considered overlapping if some of the artifact types comprising each activity set were the same. Two depositional "sets" (two different lists of artifact types that always or often are found among members of two different sets of deposits) would be considered overlapping if some of the

Table 13.1

Examples of Monothetic, Polythetic, Overlapping, and Non-Overlapping Sets of Archaeological Deposits

A Monothetic Set of Archaeological Deposits

Set 1. Member 1: deposit 1 with artifact types (attributes) A, B, C, D
Member 2: deposit 2 with artifact types (attributes) A, B, C, D
Member 3: deposit 3 with artifact types (attributes) A, B, C, D
Member 4: deposit 4 with artifact types (attributes) A, B, C, D

Two Monothetic Sets of Archaeological Deposits that are Non-overlapping

Set 1. Member 1: deposit 1 with artifact types (attributes) A, B, C, D
Member 2: deposit 2 with artifact types (attributes) A, B, C, D
Member 3: deposit 3 with artifact types (attributes) A, B, C, D
Member 4: deposit 4 with artifact types (attributes) A, B, C, D

Set 2. Member 1: deposit 5 with artifact types (attributes) E, F, G
Member 2: deposit 6 with artifact types (attributes) E, F, G
Member 3: deposit 7 with artifact types (attributes) E, F, G

No artifact type (attribute) is shared by the members of both Set 1 and Set 2, making them non-overlapping in nature.

Two Monothetic Sets of Archaeological Deposits That are Overlapping

Set 1. Member 1: deposit 1 with artifact types (attributes) A, B, C, D
Member 2: deposit 2 with artifact types (attributes) A, B, C, D
Member 3: deposit 3 with artifact types (attributes) A, B, C, D
Member 4: deposit 4 with artifact types (attributes) A, B, C, D

Set 2. Member 1: deposit 5 with artifact types (attributes) D, E, F
Member 2: deposit 6 with artifact types (attributes) D, E, F
Member 3: deposit 7 with artifact types (attributes) D, E, F

Artifact type D is shared as an attribute of the members of both Set 1 and Set 1, making them overlapping in nature.

A Polythetic Set of Archaeological Deposits

Set 1. Member 1: deposit 1 with artifact types (attributes) A, B, C, D
Member 2: deposit 2 with artifact types (attributes) A, B, C
Member 3: deposit 3 with artifact types (attributes) B, C, D
Member 4: deposit 4 with artifact types (attribute) A
Member 5: deposit 5 with artifact types (attributes) A, C, D

Two Polythetic Sets of Archaeological Deposits That Are Overlapping

Set 1. Member 1: deposit 1 with artifact types (attributes) A, B, C, D
Member 2: deposit 2 with artifact types (attributes) A, B, C
Member 3: deposit 3 with artifact types (attributes) B, C, D
Member 4: deposit 4 with artifact types (attribute) A
Member 5: deposit 5 with artifact types (attributes) A, C, D

Set 2. Member 1: deposit 6 with artifact types (attributes) D, E, F
Member 2: deposit 7 with artifact types (attributes) E, F
Member 3: deposit 8 with artifact types (attributes) D, E
Member 4: deposit 9 with artifact types (attributes) D, F

artifact types comprising each depositional set were the same. The depositional sets would be considered nonoverlapping if none of the artifact types comprising each depositional set were the same (Table 1).

Monothetic vs. polythetic sets. The distinction between overlapping and nonoverlapping sets and attribute lists refers to the *external* organization of sets. The distinction between monothetic and polythetic sets, and between monothetic and polythetic attribute lists, refers to the *internal* organization of sets. In a monothetic set, the elements of the set all share the same character states; all character states are essential to group membership. In a polythetic set, the elements share a large number of character states, but no single state is essential to group membership (Sneath & Sokal, 1973, p. 21; Clarke 1968, p. 37). In the behavioral domain, a functional set of events defined by the artifact types used in them would be monothetic if all the events used the same artifact types. The set of events would be polythetic if the events used a similar but not identical array of artifact types, and no one artifact type was essential to the occurrence of the events. In the archaeological domain, a set of functionally similar deposits would be monothetic if each deposit encompassed the same artifact types. The set of deposits would be polythetic if they shared many artifact types in common but no single artifact type were essential to the deposits' character.

By extension, if the attributes possessed by the members of a set as a whole are also possessed by *each* member, the list of attributes can be said to be monothetic. or *monothetically distributed* among members of the set. If *most* of the attributes possessed by the members of a set are shared in common by them, but no one attribute is required for membership in the set, then the list of attributes can be said to be polythetic, or *polythetically distributed* among members of the set. An activity "set" (list of artifact types characterizing a set of events) would be monothetically distributed among the events if all the artifact types in the activity set were used in each of the events. An activity set would be polythetically distributed among the events if the events involved in common most of the artifact types in the activity set, but no one artifact type were used in all the events. A depositional "set" (list of artifact types characterizing a set of deposits) would be monothetically distributed among the set of deposits if all the artifact types in the depositional set were contained in each of the deposits. A depositional set would be polythetically distributed among a set of deposits if the deposits held in common most of the artifact types in the depositional set, but no one artifact type were required of a deposit to be a member of the set of deposits (Table 1).

Continuous scale analogs. Nonoverlapping vs. overlapping and monothetic vs. polythetic characterizations of the organization of sets and attribute lists can be redefined on continuous scales. One can speak of sets and attribute lists that are more or less overlapping, or more or less polythetic/polythetically distributed. Two sets, and their defining attribute lists, become *more overlapping* as the number of attributes shared by the sets, compared to the total number of attributes involved, increases. Thus, the degree of overlap between two sets, A and B, can be expressed as

$$O_{ab} = \frac{C_{ab}}{C_a + C_{ab} + C_b} \times 100\% \tag{1}$$

where O_{ab} is the percent overlap of the sets; C_{ab} is the number of attributes shared by sets A and B; and C_a and C_b are the number of attributes uniquely defining sets A and B, respectively.

A single set becomes *more polythetic* and its defining list of attributes becomes more *polythetically distributed* as smaller percentages of its attributes become shared by higher percentages of its members, on the average. Thus, the degree of polytheticness of a set can be expressed by a frequency distribution: each class of the distribution represents a range of percentages of attributes and the value of each class is the percentage of all possible pairs of members sharing given percentages of attributes (Fig. 3). It is possible to summarize the degree of polytheticness of a set in a single statistic using the mean or median of the distribution (see p. 345 & Table 3).

Building the Models

The defined monothetic-polythetic and nonoverlapping-overlapping dimensions can serve as a framework for developing alternative models of organization of artifact types. Such models might pertain to the distribution of artifact types among and within sets of behavioral events in the behavioral domain, or to their distribution and spatial arrangement among and within sets of archaeological deposits in the archaeological domain.

First Approximation of the Models, Using Variation along the Monothetic-Polythetic Dimension, Alone

Consider variation in the internal organization of sets along the monothetic-polythetic dimension, alone. Six models of organization can logically be defined along this dimension (although some may not occur in reality). These are shown in Figure 4.

The six models fall into two categories along the monothetic-polythetic dimension. Models 1 through 4 each illustrate a monothetic set of groups of artifacts, each group always possessing artifact types X and O. Models 5 and 6, by contrast, each illustrate a polythetic set of groups of artifacts; not all groups have both types of artifacts.

It is obvious, however, that there is more diversity among the models in their forms of organization than is indicated by the simple dichotomy of monothetic vs. polythetic structure. Nor is this diversity one of degree of polytheticness. To describe this variability, more basic mathematical concepts, defining a dimen-

Set: Member 1 has attributes A B C D
Member 2 has attributes A B C
Member 3 has attributes B C D
Member 4 has attribute A
Member 5 has attributes A C

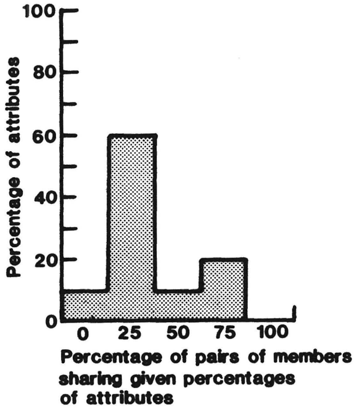
Data for Constructing Frequency Distribution

Pairs of members	Number of attributes shared
1 - 2	3
1 - 3	3
1 - 4	1
1 - 5	1
2 - 3	2
2 - 4	1
2 - 5	1
3 - 4	0
3 - 5	1
4 - 5	1

Number of members, n, = 5
Total number of pairs of members = $\frac{n!}{2[n-2]!}$ = 10

1 pair of members share no attributes (0% of the attributes) with other members
6 pairs of members share only 1 attribute (25% of the attributes) with other members
1 pair of members share only 2 attributes (50% of the attributes) with other members
2 pairs of members share 3 attributes (75% of the attributes) with other members
0 pair of members share 4 attributes (100% of the attributes) with other members

Degree of Polytheticness of the Set



Mean polytheticness 35%

Fig. 13.3. The degree of polytheticness of a set can be defined by a frequency distribution that summarizes the percentage of the set's attributes shared by given percentages of pairs of members of the set.

sion both underlying and crosscutting the monothetic-polythetic one, must be explained.

Symmetrical vs. asymmetrical coarrangements (Pielou, 1964). These concepts are most easily explained in spatial terms pertinent to the domain of archaeological

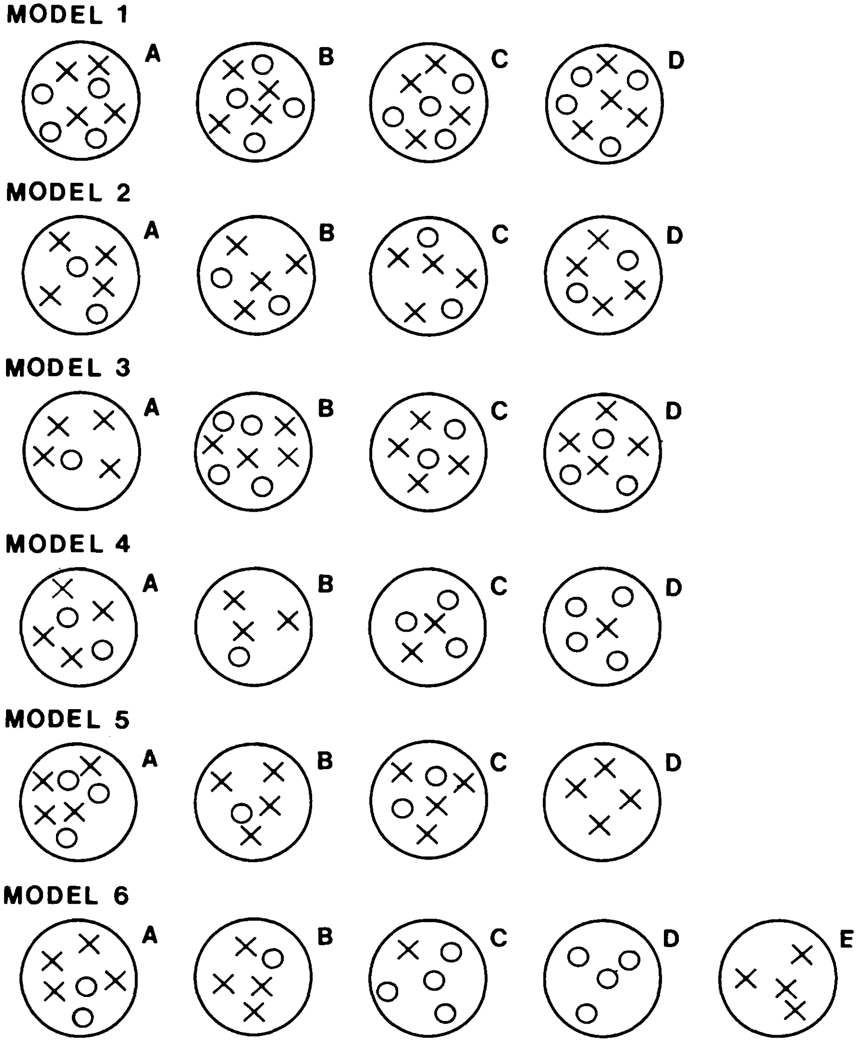


Fig. 13.4. Six models of organization of artifact types among archaeological deposits or behavioral events fall along a monothetic-polythetic continuum. Only one pair of types within the same set of deposits or events is shown; other types are assumed to have analogous forms of organization. The organizational characteristics of each model are described in Table 13.2.

deposits, but can be extended to the behavioral domain of events. Within a given area of reference, two types of entities are said to be symmetrically coarranged if wherever an item of one type occurs, an item of the other always occurs, and vice versa. In nearest-neighbor terms, this means that whenever one type of entity is a second's nearest neighbor, the second type of entity is always the first's nearest neighbor (Fig. 5a). A symmetrical coarrangement of two types of entities can occur only when they have equal densities and items of the two types *always can pair*, in addition to their having similar distributions. In contrast, asymmetrical coarrangements between two types of entities occur when they are scattered in a similar pattern over the same area, but in different densities. Items of the lower density type of entity always have items of the

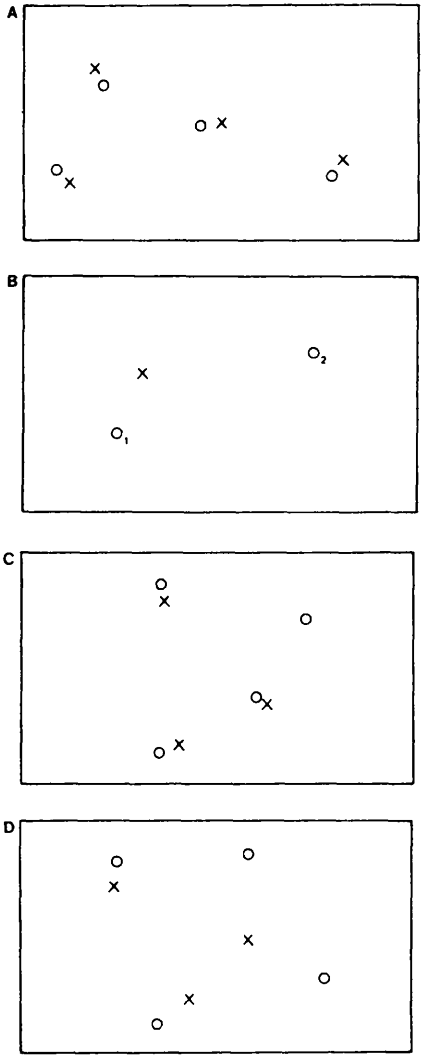


Fig. 13.5. Symmetry and asymmetry among artifact types. (A) A symmetrical coarrangement of two artifact types, X and O, defining a monothetic set. (B) Asymmetry in nearest neighbors. Artifact X is artifact O_2's nearest neighbor of the opposite kind, but O_2 is not X's nearest neighbor of the opposite kind. Artifact O_1 is artifact X's nearest neighbor of the opposite kind. (C) An asymmetrical coarrangement of two artifact types, X and O. (D) An asymmetrical arrangement of two artifact types, X and O, showing weaker coarrangement.

higher density type near them, but items of the higher density type only sometimes have items of the lower density type near them. Nearest neighbor relationships are not reciprocal (Fig. 5b-5d).

Magnitude and direction of asymmetry. Asymmetrical coarrangements of entities of two types can differ from one area of reference to another in two manners: the magnitude of their asymmetry and the direction of their asymmetry. The magnitude of asymmetry characterizing a coarrangement of types is equivalent to the *difference in the average areal densities* of items of the two types within the reference area. The direction of asymmetry refers to *which type* predominates in the reference area. For example, in Model 4, reference areas *A* and *B* exhibit asymmetrical coarrangements that differ in the magnitude of their asymmetries: the relative densities of types *X*:*O* are 4:2 in area *A* and 3:1 in area *B*. Reference areas *B* and *D* have asymmetrical coarrangements that differ in the direction of their asymmetry: type *X* predominates in area *B* whereas type *O* predominates in area *D*.

Scale of asymmetry. It is also possible to distinguish the *scale* of the area of reference over which asymmetry is assessed. *Global* assessments over an area at large, more *local* assessments within a subarea of it, (e.g., within one cluster of items in an area having many clusters), and *very local* assessments pertaining to pairs of items, are possible. For example, in Model 3, entity types *X* and *O* are coarranged in an asymmetrical manner considering the global area containing *a, b, c,* and *d*. They are arranged in a symmetrical manner if one considers only the more local area, *B*.

In a clustered coarrangement of two types where there exist several groups of items of the two types (e.g., Fig. 4), the symmetric-asymmetric dimension can crosscut or parallel the monothetic-polythetic dimension. The situation depends on the scale of the area over which each dimensional assessment is made and the size of the groupings of items.

1) If the area of reference for both dimensions is defined globally so as to include several groups of items, each with more than a pair of items (e.g., groups *A, B, C, D,* and *E* in any of the models in Fig. 4), then the symmetric-asymmetric dimension will *crosscut* the monothetic-polythetic dimension; the relationship between them will be indeterminant. For example, all of Models 1 through 4 illustrate globally monothetic sets, yet Models 1 and 4 exhibit a globally symmetrical relationship between types *X* and *O* while Models 2 and 3 exhibit globally asymmetrical relationships between the types. Also, models illustrating globally monothetic sets (Numbers 2, 3, 4) as well as models illustrating globally polythetic sets (Numbers 5, 6) exhibit globally asymmetrical relationships between the two types.

2) If the area over which the monothetic-polythetic dimensional assessment is made is defined globally so as to include several groups (*A, B, C, D,* and *E*), each with more than a pair of items, but the reference area for assessing symmetrical-asymmetrical relations is defined more locally, focusing on indi-

vidual groups, then the symmetrical-asymmetrical dimension will sometimes crosscut, sometimes parallel the monothetic-polythetic dimension, depending on the aspect of asymmetry considered. (a) Considering only whether asymmetry *occurs* and its *direction*, the two dimensions will *crosscut* each other, defining an indeterminant relationship between them. For example, all of Models 1 through 4 illustrate globally monothetic sets, yet Model 1 exhibits local (within group) symmetry between types *X* and *O* while Models 2 through 4 exhibit local asymmetry between the types. Also, models illustrating globally monothetic sets (Numbers 2, 3, 4) as well as models illustrating globally polythetic sets (Numbers 5, 6) exhibit locally asymmetric relationships between the two types. (b) On the other hand, considering the *magnitude* of asymmetry, and in particular whether asymmetry occurs to the extreme in some groups of items such that one type does not occur in them, then the symmetric-asymmetric dimension *parallels* and determines the monothetic-polythetic dimension. For example, in Models 5 and 6, the magnitude of local asymmetry is so large in one or two of the groups of items that one type is absent from them. In Models 1 through 4, this extreme amount of local asymmetry does not occur; each group of items includes items of both types. In these circumstances, *by definition*, Models 5 and 6 represent globally polythetic sets of groups while Models 1 through 4 represent globally monothetic sets of groups.

3) Finally, the scale of the area over which the monothetic-polythetic dimensional assessment is made can be global but the size of the groups of interest can be reduced to very local *pairings* of items rather than the multi-item groups considered before. Additionally, the scale of the area for assessing symmetric-asymmetric dimensional relations can be defined very locally so as to include only pairs of nearest neighbors. In these circumstances, the symmetry-asymmetry dimension will *parallel* and determine the monothetic-polythetic dimension. A very locally symmetrical coarrangement of items of two types *always* will define a monothetic set of pairs of items. In a symmetrical coarrangement, items of opposite types always are each other's nearest neighbors, implying that each pair of items in the global reference area (members of the set) is characterized by one item of each type, i.e., the set of pairs is monothetic. A very locally asymmetrical coarrangement of items of two types *always* will define a polythetic set of pairs of items. In an asymmetrical coarrangement, items of opposite types are not always nearest neighbors, implying that pairs of items in the global reference area (members of the set) sometimes but not always are characterized by one item of each type, i.e., the set of pairs is polythetic.

In developing models of organization of artifacts, it is important that the scales of the areas of assessment for the symmetric-asymmetric dimension and the monothetic-polythetic dimension, as well as the size of groups of items, be kept clear. This was not always done in the initial article (Carr, 1984) of the series that includes this one. The concept of polythetic sets of deposits or events was introduced using asymmetrical relationships between types at the *local* scale of *multi-item* groups, while the dependence of global polythetic organization on asymmetry was argued at the *very local* scale of *pairs* of items. The discussion just presented should allow modeling of artifact organization in a more consistent manner, as well as provide insight into organizational diversity not previously realized.

The six models. Using the distinction between symmetrical and asymmetrical coarrangements, as well as variation in the magnitude, direction, and scale of asymmetry, it is possible to construct the four globally monothetic models of artifact organization and the two globally polythetic ones in Figure 4, and to specify the organizational characteristics distinguishing them (Table 2). The six models differ in both global and local aspects of their organization. Model 1 differs from all the rest in that globally asymmetrical relations between artifact types, as well as locally asymmetrical relations between them (within groups of items), are not permitted. Models 2 through 6 differ from each other in various aspects of locally asymmetrical relations between types of items. For example, Model 2 does not permit local asymmetry to vary in magnitude from one group of items to the next, while Models 3 through 6 do. Models 3 and 5 do not permit local asymmetry to vary in direction from group to group, while Models 4 and 6 do.

The distinguishing characteristics of some of the models can also be summarized in terms of concepts that are more familiar than the various aspects of asymmetry, though less precise. In Model 1, artifacts of each type occur in 1:1 proportions, both globally, and locally within groups. In Model 2, the artifact types occur in the same proportion in each group of items, but the particular proportion is not specified. In Models 3 and 4, the organization of artifact types is more variable from group to group; the proportions of artifact types within groups can vary among groups. However, all types at least *occur* in each group. Models 5 and 6 have the most variable organization of artifact types among groups. Not only do the proportions of artifact types within groups vary from group to group, but some groups do not have occurrences of some kinds of artifacts.

The six models can be used to describe the organization of artifact types into sets within both the behavioral and archaeological domains. If the models are taken to describe archaeological organization, the groups of artifacts A through E in Figure 4 represent deposits forming either a globally monothetic or globally polythetic set. The two artifact types, X and O, are considered a depositional "set." If the models are taken to describe behavioral organization, the groups of artifacts represent events, again forming either a globally monothetic or globally polythetic set. The two artifact types, X and O, are considered an activity "set."

The several models can be viewed as simply *alternative* forms of organization of artifact types. However, as hinted above, they also can define a *sequence* of organizational forms. The sequence ranges from lower-numbered models hav-

Table 13.2

Mathematical Characteristics of the Six Models of Organization of Artifact Types in Figure 3

Characteristics	*Models*					
	1	*2*	*3*	*4*	*5*	*6*
Asymmetry within groups of artifacts allowed for one or more pairs of types	−	+	+	+	+	+
Differences between groups in the magnitudes of their asymmetries allowed for one or more pairs of types	−	−	+	+	+	+
Differences between groups in the directions of their asymmetries allowed for one or more pairs of types	−	−	−	+	−	+
Asymmetry within groups taken to the extreme, where one type, of one or more pairs of types, does not occur in some groups	−	−	−	−	+	+
Global monothetic or polythetic organization using A, B, C, D, E as groups of interest (Fig. 3)	monothetic	monothetic	monothetic	monothetic	polythetic	polythetic
Local monothetic or polythetic organization using pairs of items as groups of interest	monothetic	polythetic	polythetic	polythetic	polythetic	polythetic

ing very specific forms of organization of types among groups to higher-numbered models encompassing more variable organization.

It is also possible to view each model as more than just a *description* of the organizational relations that can occur between artifact types within sets of deposits or events. Rather, each can be seen as a *standard of organization*, which stipulates, for any given data set, the organizational relations among types that *minimally are required of them to be considered coarranged and interpreted as defining a set* of deposits or events. The sequence of models would then define an *ordered series of constraints* on the relationships among types, ranging from the most restrictive to the most permissive specifications necessary for the types to define a set.

It is advantageous, for several reasons, to view the models as a sequence and as standards of organization. 1) Site formation processes often are viewed as a series of actions cumulatively bringing increasing entropy (Ascher, 1968), bias (Cowgill, 1970), or distortion (Schiffer, 1972, 1976) to relationships among artifacts that once were more direct reflections of the behavioral system that produced them. By viewing the models as a sequence defining more and more variable organizational relations among types, it becomes possible to *link the models to a series of site formation processes* of cumulatively increasing number and disordering effects. Any of the models in the sequence can serve as the base-line organization initially produced by the behavioral system. The following, less constraining models then indicate organizational changes resulting from depositional and post-depositional formation processes.

2) Quantitative and statistical techniques vary in the degree to which their assumptions about a data set's structure are specific and constraining. In particular, techniques can vary in whether they assume ratio, interval, ordinal, or nominal scale relationships among entities to be significant, and whether they assume monothetic or polythetic relationships to be significant (Carr, 1984). They can be ranked in reference to these criteria, with ratio scale and monothetic organizational relations being most constraining. Since the models of artifact organization can be ordered into a parallel sequence, in which constraints on the relationships among types range from ratio to nominal scale specifications and monothetic to polythetic specifications, it becomes possible to *link each model to techniques* appropriate for describing its relevant structure.

3) As a consequence of the linkages described in points 1 and 2, it is possible to create a series of constructs, each of which relates a model of artifact organization to formation processes capable of generating such organization and to techniques appropriate for describing that organization. The combined process-model-technique constructs can serve as entry models that facilitate the linkage of an intrasite spatial data set to the techniques most appropriate for its analysis. This can be done in the following way. Suppose one knows something about the formation processes responsible for a study area and their effects on artifact organization, or can suggest some of the formation processes and their effects that likely occurred in the area on the basis of its behavioral and

environmental context. In this circumstance, the study area can be associated with and assumed to share in the artifact organizational characteristics of one or a few of the models of artifact organization, on account of the formation processes that the area and model(s) hold in common. Furthermore, the linkages between models and techniques allow the study area to be associated with one or a few appropriate analytic techniques.

Expansion of the Models to Include Variation along the Nonoverlapping-Overlapping Dimension

The six models of organization of artifact types constructed to this point are distinguished by characteristics along the monothetic-polythetic dimension of organization, alone. It is possible to elaborate them further from a set-theoretic perspective by introducing organizational diversity along the nonoverlapping-overlapping dimension. This can be achieved by duplicating the models in Table 2, resulting in twelve models: one set of six with the additional characteristic that sets of deposits or events are nonoverlapping, the other with the additional characteristic that sets of deposits or events are overlapping.

The variation in form of artifact organization that the models exhibit along the nonoverlapping-overlapping dimension, like that which they express along the monothetic-polythetic dimension, can be viewed as a *sequence.* The sequence ranges from an ordered form of organization not involving any overlap between sets of events or deposits to a highly variable form involving their overlap by up to all but one characteristic artifact type, each. Also, the nonoverlapping and overlapping models can be seen as *standards of organization,* stipulating for any given data the organizational relationships among sets of events or deposits that minimally are required for them to be interpreted as discrete sets. The advantage of these perspectives is the same as those just described: the organizational models can be linked to formation processes and analytic techniques and altered into entry models.

Complex Models

To present, it has been assumed that some single model of organization of artifact types is adequate for characterizing all the relationships among types that occur archaeologically or behaviorally within a study area. For example, if one pair of artifact types within an activity set or depositional set exhibits asymmetry with local variation in the direction of asymmetry, it has been assumed that all the other artifact pairs in that set and within other sets also exhibit that characteristic. Clearly, the situation can be more complex, with some type-pairs exhibiting one kind of organization and other type-pairs exhibiting others.

It is possible to specify all the permutations of the twelve forms of organization that might arise in the behavioral or archaeological domain within any single site encompassing multiple artifact types. And in some rare instances, it may be possible to classify a study area in relation to such permutations. However, considering the practical aim of this paper to provide models *facilitating linkage* of archaeological data structures to appropriate analytic techniques, such a detailed classification process does not seem pertinent. To classify a study area in such detail when attempting to determine the most appropriate technique for its analysis would require nearly as much knowledge about the area as that being sought through analysis.

In light of this practical limitation on classifying an archaeological data set, yet recognizing that a study area may exhibit multiple organizational relationships among different artifact pairs, some of which may be known, an alternative approach is suggested. If a study area is known or suspected to exhibit several different kinds of relationships between different pairs of artifact types, in concordance with several different models of organization, then the area should be characterized by those few models that represent the *most frequently occurring* organizational relationships in it. This will lead to the data set being examined by several different techniques that make different assumptions about the data's structure, and will possibly result in the definition of depositional sets that vary in composition. A composite picture of depositional set composition can then be constructed logically from the several solutions, bearing in mind the constraints under which they were derived, where those constraints conflict with formation processes, and where the constraints likely have produced erroneous representations. This kind of evaluation becomes possible only when working within a pattern-recognition framework involving knowledge about the formation processes responsible or probably responsible for the study area, as opposed to a completely inductive pattern-searching framework not involving this information.

Alternatively, one might think it appropriate to characterize the data by that *one* model requiring the *least constraining* relationships among artifact types, leading to the examination of the data set with one technique that assumes more variable organization of the data. However, this approach can lead to solutions just as erroneous as those obtained when using only one technique that assumes a more restrictive organization, depending on the actual forms of organization exhibited by the data. A technique that assumes the significance of only least constraining relationships among data items is as focused in its description of patterning as a technique that assumes the significance of only restrictive relationships; the difference is in only the *form* of patterning recognized, not the *range* of forms of patterns recognized. A "least constraining" method should not be confused with a "robust" one. Thus, this alternative seems inappropriate. An illustration of this point is made in the Pincevent example analysis, later.

Finally, it should be realized that the problem posed by study areas having depositional sets with multiple forms of organization is distinct from the problem of pooled *contradictory* structures. Moreover, the latter can be resolved under some conditions with Fourier and filtering methods, whereas the former cannot.

A Continuous-Scale Analog of the Twelve Models

Thus far, several discrete models of organization of artifact types in the behavioral and archaeological domains have been constructed, each model distinguished by nominal scale characteristics. Alternatively, it is possible to define a single hypervolume continuum of organizational variation using continuous scale, orthoganal dimensions analogous to the nominal scale characteristics.

Such a construct might be used to describe artifact organization within the behavioral or archaeological domains for theoretical purposes. It might also be used after an intrasite spatial analysis in order to specify precisely the organization of artifacts within a study area compared to that within other study areas. However, the construct would not be useful in characterizing the organization of artifacts within an area prior to spatial analysis and facilitating linkage of the data structure to an appropriate analytic technique; this would require more detailed information on the organization of artifacts within the site than would normally be available prior to analysis.

The dimensions that may be used to define the desired hypervolume are given in Table 3. Dimension 1 measures, over all deposits/events within a set, the average magnitude of local asymmetry exhibited by a type-pair defining that set, in turn averaged over all defining type-pairs for the set(s) of interest. It is analogous to the organizational characteristic listed in the second column of Table 2 for the discrete models. The measure is not affected by whether the magnitude or direction of asymmetry of types varies or is uniform among deposits/events (third, fourth columns of Table 2). Dimension 2 measures, over all deposits/events within a set, the variance among deposits/events in the magnitude of local asymmetry expressed by a type-pair defining the set, in turn averaged over all such type-pairs for the set(s) of interest. Since large variability among deposits/events in the magnitude of asymmetry between a type-pair can associate with a change in the direction of its asymmetry, dimension 2 also measures, over all deposits/events within a set, the variability or uniformity in the direction of asymmetry expressed by a type-pair defining the set, averaged over all such pairs for the set(s) of interest. The measure is analogous to the organizational characteristics listed in the third and fourth columns of Table 2 for the discrete models. Dimension 3 measures the percentage of deposits/events in a set having given percentages of the artifact types defining it (including deposits/events having 0% of some types), averaged over all depositional sets of interest within the study area. It is equivalent to the average degree of global polytheticness of the sets in the study area, where the global polytheticness of any single set is calculated as shown in Figure 3, and described pre-

Table 13.3

Dimensions for Defining a Continuous Scale Hypervolume of Intrasite Artifact Organization

Dimension 1. Average Magnitude of Local Asymmetry, A.

Let p = any pair of types within the same depositional set, for any of the sets defined by analysis
c_p = an artifact cluster or arbitrary analytical unit within the study area, having the pair of types, p
X_{pc_p} = the absolute value of the difference between the number of items of the two types in one pair, p, within cluster/unit c_p, divided by the total number of items of both types in the cluster/unit
n = the total number of clusters/units, c_p
m = the total number of pairs of types, p.

Then

$$A = \frac{\sum_{p=1}^{m} \left(\frac{\sum_{c_p=1}^{n} X_{pc_p}}{n} \right)}{m}$$

Dimension 2. Average Variability in Magnitude and Direction of Local Asymmetry, V.

Let p, c_p, n, and m be as before, and
X_{pc_p} = the difference between the number of items of the two types in the pair p within cluster/unit c_p, divided by the total number of items of both types in the cluster/unit
$var_{c_p}()$ = the variance of the measure in parenthesis over all clusters/units having the pair of types p.

Then

$$V = \frac{\sum_{p=1}^{m} var_{c_p}(X_{pc_p})}{m}$$

Dimension 3. Average Global Polytheticness of Sets, P.

Let d = any set of deposits characterized by a number of artifact types
p_d = any percentage of all the artifact types defining the set of deposits, d
X_{p_d} = the number of pairs of deposits sharing the given percentage, p_d, of all the artifact types defining the set of deposits, d
n_d = the total number of pairs of deposits with one or more of the artifact types defining the set of deposits, d
m = the total number of sets of deposits.

Table 13.3 (cont.)

Then

$$P = \frac{\sum_{d=1}^{m} \left(\frac{\sum_{p_d=1}^{100} (X_{p_d})(p_d)}{n_d} \right)}{m}$$

Dimension 4. Average Degree of Overlap among Sets, O.

Let a = one set of deposits/events defined by a certain list of artifact types
b = another set of deposits/events defined by another list of artifact types
C_{ab} = the number of artifact types shared by sets a and b
C_a, C_b = the number of artifact types uniquely defining sets a and b, respectively
n = the number of pairs of sets of deposits/events within the study area.

Then

$$O = \frac{\sum_{ab}^{n} \left(\frac{C_{ab}}{C_a + C_{ab} + C_b} \times 100\% \right)}{n}$$

viously (pp. 333-334). The measure is analogous to the nominal scale organizational characteristic listed in the fifth column of Table 2. Dimension 4 measures the average degree of overlap among all pairs of sets of deposits/events that are of interest within a study area. It is analogous to the nominal scale, nonoverlapping-overlapping dimension discussed previously.

The continuous dimensions of organization just established define the average conditions within a study area. The formulae may be modified in obvious ways to define the variance of such conditions around the norms.

LINKING THE MODELS OF ORGANIZATION WITH FORMATION PROCESSES

In this section, the twelve discrete models of organization of artifact types will be taken to represent structures within the archaeological domain. The aim is to link the models to various formation processes that can produce such structures. This linkage represents a critical step in formulating a series of entry models, each of which is composed of a model of artifact organization, an enumeration of the formation processes capable of generating that form of organization, and a list of mathematical techniques assuming that form of organization. The resulting entry models will facilitate the linkage of intrasite spatial data sets to techniques appropriate for their analysis.

The organization of artifacts within the archaeological record is the product of two phenomena: 1) their previous organization in the behavioral domain, and 2) the formation and disturbance processes transferring and transforming

Table 13.4

Processes Responsible for Absences of Artifact Types from Events or Deposits where they Might be Expected in the Behavioral or Archaeological Domains

Processes Responsible for Absences of Artifact Types from Events in Which Their Use Might Be Expected	*Processes Likely to Act Uniformly over All of Site?*
1. Several alternative tool types may be used to accomplish the same ends.	no
2. Some specific tasks within a general activity may be optional, making the use of some tool types optional.	no
Processes Responsible for Absences of Artifact Types from Deposits in Which They Might Be Expected	
1. The cultural formation processes in the behavioral domain stated above.	no
2. Artifact types comprising the same activity set may enter the archaeological domain as subsets separated in different locations of their manufacture, use, storage, or discard, none of which need coincide (Schiffer, 1972).	no
3. Large artifact types may be purposefully discarded in out-of-the-way, secondary trash deposits while smaller artifact types belonging to the same activity set may be discarded or lost anywhere without much annoyance (McKellar, 1973).	yes
4. Differential wear and breakage rates of different artifact types that belong to the same activity set and that are curated.	no

that organization from the behavioral to the archaeological domain. It is necessary to first consider the possible forms of organization of artifacts in the behavioral domain and their causes, as a baseline.

Processes Leading to Forms of Organization in the Behavioral Domain

Any of the twelve models of organization—encompassing monothetic and polythetic, nonoverlapping and overlapping forms—may describe the configuration of artifact types within and among sets of events in the behavioral domain. The basic processes responsible for variation along the monothetic-polythetic and nonoverlapping-overlapping dimensions are few. Monothetic-polythetic variation can result from the use or lack of use of *alternative* tool types for accomplishing the same ends in similar events, or of *optional* tool types for accomplishing optional subtasks within similar events. Nonoverlapping-overlapping variation can result from the use or lack of use of the same multipurpose tools in differing events (Tables 4, 5).

Table 13.4 (cont.)

5. A multipurpose artifact that is associated with more than one activity set can be deposited with artifacts from only one of the activity sets.	no
6. A multitype artifact that has several edges used for different purposes and is associated with more than one activity set can be deposited with artifacts from only one of the activity sets.	no
7. A broken artifact of one type may be recycled and made into an artifact of another type in a different activity set.	yes/no, depending on type
8. "Mining" of abandoned parts of a site or an abandoned site by prehistoric individuals or contemporary artifact collectors (Ascher, 1968; Reid, 1973; Schiffer, 1977, p. 26).	no
9. Effects of cultural and natural post-depositional processes that increase the entropy of the archaeological record.	
a. trampling by site occupants.	no
b. carnivore activity (Binford, 1977a, 1981b; Yellen, 1977b; Wandsnider & Binford, 1982).	no
c. plowing (Roper, 1976; Trubowitz, 1981; Lewarch & O'Brien, 1981).	yes
d. water washing, wind sorting (Shakley, 1978; Behrensmeyer & Hill, 1980; Limbrey, 1980).	no
e. biologically caused soil movements: pedoturbations caused by the burrowing actions of mammals, insects, and earthworms (Stein, 1980); treefalls.	no
f. meteorologically and geologically caused soil movements: soil creep, solifluction, cryoturbations, aquiturbations (Wood & Johnson, 1978).	no
10. Lack of preservation of bone items of a class.	no
11. Incomplete recovery of artifacts during excavation.	no
12. Misclassification of an artifact's function.	no
13. Use of an overly divisive functional classification scheme for typing artifacts.	yes
14. Use of a nonfunctional artifact classification scheme.	?

Variation along the nonoverlapping-overlapping dimension. It is easy to think of activity sets within primitive technologies that contain only single-purpose tools and that define nonoverlapping sets of events. However, a wide variety of activity sets that contain multipurpose tools and define overlapping sets of events are also known. Carr (1984, Table 1) and Cook (1976) reference many ethnographic, ethnoarchaeological, and tool experimental studies that document these two forms of organization. Microwear studies (e.g., Keeley, 1977, 1978; Odell, 1977) which document the use of prehistoric artifacts on single or multiple kinds of raw materials, provide further evidence of this kind of variation in tool use and organization in the past. For example, Keeley has shown

Table 13.5

Processes Responsible for Overlap among Sets in the Behavioral and Archaeological Domains

Processes Responsible for Overlap among Sets of Events in the Artifact Types Defining Them	*Processes Likely to Act Uniformly over All of Site?*
1. Single-type tools with one functional edge (e.g., prismatic blades) may have multiple purposes and be used in several different sets of events with different tool types (e.g., Cook, 1976).	yes
2. Multi-type tools with several edges used for different purposes (e.g., a Swiss Army knife) may be used in several different sets of events with different tool types.	yes
Processes Responsible for Overlap among Sets of Deposits in the Artifact Types Defining Them	
1. Cultural formation processes in the behavioral domain, stated above.	yes
2. *Systematic* spatial overlap of different kinds of activities, e.g., "agglomerated activity areas" (Speth & Johnson, 1976; Yellen, 1977a).	by definition
3. Redeposition of primary refuse generated by different kinds of activities in different areas *systematically* in the same formalized trash areas.	by definition
4. Extensive post-depositional smearing and blending of primary refuse from repeatedly neighboring activity areas of different kinds by natural processes of several kinds.	
a. plowing, if the artifact distribution comes from a surface survey (Roper, 1976; Trubowitz, 1981; Lewarch & O'Brien, 1981).	yes
b. trampling by the occupants of the site (Ascher, 1968).	no
c. carnivore action (Binford, 1981b; Yellen, 1977b; Wandsnider & Binford, 1982).	no
d. pedoturbations by the burrowing action of larger mammals.	no
e. soil creep, solifluction, cryoturbations, aquiturbations (Wood & Johnson, 1978).	no
f. water washing (Shackley, 1978; Behrensmeyer & Hill, 1980).	no
5. Misclassification of an artifact's function.	no
6. Use of a nonfunctional artifact classification scheme.	?

that endscrapers at the Epipaleolithic site of Meer II, Belgium, and possibly those of the later Paleolithic of Europe in general, were used almost exclusively on dry hide to cure or grain it (1978; Table 15, pp. 74-79). In contrast, knives at the site may have been used systematically on a diversity of materials (grasses, cane, mat; 1978, pp. 82-83), as were becs (bone or antler, hide; 1978, Table 19).

Variation along the monothetic-polythetic dimension. To see how organizational forms along this dimension might be created through the use of alternative tool types accomplishing the same ends in a set of events, one need only envision a set of carpentry events involving a hammer, nails, a screwdriver, screws, and a saw. A particular set of building tasks might always involve the use of all five artifact types, with both screws and nails being used to assemble cut pieces of wood (Model 2, 3, or 4). Or perhaps screws (and hence, the screwdriver) might be deleted from some of the operations (Model 5 or 6). For a set of tasks involving both screws and nails, screws might be used always in just a few critical positions, nails always predominating the tasks (Model 2 or 3); or the screws and nails might be used in widely varying proportions, neither one predominating in all the tasks (Model 4). In contrast, some kinds of activities always restrictively require certain tool types in a 1:1 ratio and do not permit the use of alternative tool types (Model 1). The use of mono and metate to grind grain or pound large seeds, roots, bulbs, or meat (Kraybill, 1977; Riddell & Pritchard, 1971; Driver, 1961, p. 93; Wheat, 1972, p. 117), mortar and pestle to crack nuts (Battle, 1922; Swanton, 1946; Waugh, 1916, p. 123) or maul and axe to fell trees (Swanton, 1946) are examples. Again, microwear studies document both single or multiple kinds of tools used for single kinds of tasks, illustrating variability in tool organization along the monothetic-polythetic dimension. For example, Keeley (1978, Table 19, pp. 79-80) concludes that becs and many forms of burins had equivalent functions (boring bone or antler) at Meer II, while he does not find any functional equivalent for endscrapers used in curing dry hides.

Processes Leading to Forms of Organization in the Archaeological Domain: The Monothetic-Polythetic Dimension

In the archaeological domain, the relationships that exist between artifact types within and among sets of deposits usually are no more constraining than the baseline organization of types in the behavioral domain from which they are derived. Generally, the net effect of formation processes is to increase the amount of *randomness and variety* in the relationships exhibited between artifact types as they are transferred from the behavioral to the archaeological domain and then altered within the archaeological domain (Ascher, 1968).

The models of organization along the monothetic-polythetic dimension are useful for describing these transformations. The models define a sequence of organizational configurations that range from those encompassing highly constrained relationships among types (Model 1) to those exhibiting more variable organization (Model 6). Differences between one or more successive models in the sequence can be used to define the changes that can occur among types as they are transferred to and within the archaeological domain. For example, suppose several types of artifacts form an activity set and are distributed among events within a site in the globally monothetic manner expressed in Model 3. It is expectable that they will usually become distributed among deposits in the archaeological domain in a manner that is equally or less constraining—perhaps monothetically (Model 3 or 4) or perhaps polythetically (Model 5 or 6).

Site formation processes can not only introduce randomness and variety into the relationships among artifact types; they also can cause *systematic biases*[2] in artifact type relationships away from the norm expressed in the behavioral domain (Cowgill, 1970; Schiffer, 1982). These changes, as well, can be described by the differences between some successive models in the sequence. For example, the change from Model 1 to Model 2 involves a change in the proportions of artifact types in the same magnitude and direction for *each* group of artifacts. The change from Model 1 or 2 to Model 3 involves a change in proportions only in the same direction for each group.

There are exceptions to the "increasing-entropy" characterization of the net effect of formation processes. Some of these pertain to natural processes that can lead to the spatial clustering of previously dispersed artifacts (e.g., through the action of earthworms (Ascher, 1968); freeze-thaw cycles; expansion-contraction cycles in vertisols, salinization and cracking of the soil; soil creep [Wood & Johnson, 1978]). Although most familiar, these processes are of less importance here because they usually do not operate *selectively* on *particular types* and the spatial relations among them (except when the types exhibit marked size or density differences). However, other formation processes—especially cultural ones—can operate selectively on certain artifact classes and the relationships among them, causing more constrained organization in the archaeological domain than the behavioral. 1) *Caching* can cause artifact types distributed polythetically among a set of events in the behavioral domain to enter the archaeological domain as a monothetic set. For example, consider screws and a screwdriver, nails and a hammer, which are used alternatively in different carpentry events by different carpenters along with a saw and file. This configuration of artifacts defines a polythetic set (Model 5 or 6). However, all the artifact types might be stored on each carpenter's workbench, defining a monothetic set (Model 3 or 4). 2) *Reuse of activity areas* for the same purposes can cause an increasingly constrained artifact organization. Suppose that functionally alternative artifact types are distributed polythetically among a set of events that occur in several different activity areas (Models 5 or 6). If events of that kind are performed repeatedly in those areas, with the particular alternative types used in each area varying randomly over time, and if artifacts are deposited relatively expediently, then over time, the inventory of artifact types found in each area will become more similar, ultimately defining a monothetic set of deposits (Models 2, 3, or 4) (Carr, 1984). 3) Similarly, if the refuse from each such activity area is repeatedly moved to *common refuse dumps* after each event, the inventories of artifact types in the refuse dumps will become more similar to each other, ultimately defining a monothetic set of refuse areas.

Considering the more common sequence in which greater net disorganization is introduced by site formation processes, it is possible to specify more precisely how formation processes can produce and be linked to variation in artifact organization like that exhibited by the several models along the monothetic-polythetic dimension. This can be achieved in part by using the concept of *unexpected absences*, which is defined as follows.

Assume that any of the five most constraining models in Figure 3 represent the organization of artifact types in the behavioral domain and that the lesser constraining models in the sequence represent artifact organization in the archaeological domain. It then may be said that "unexpected absences" of artifacts of some types in one or more groups (A, B, C, D, or E) occur in the less constraining models compared to the more constraining baseline models. For example, if Model 1 represents artifact organization in the behavioral domain while Model 2 represents artifact organization in the archaeological domain, then Model 2 exhibits "unexpected absences" of artifact type O: there is one item of type X for each item of type O in Model 1, but fewer items of type O in Model 2. In this context, unexpected absences represent the effects of formation processes that can increase the variability of relationships among artifact types. For example, in Model 1, each artifact of type X has a nearest neighbor of type O, whereas in Model 2, sometimes it has a nearest neighbor of type O, sometimes of type X.

The concept of unexpected absences and unexpected forms of organization of artifact types in the archaeological domain implies—in opposition to such forms—an ideal, expected form of organization of artifacts in the archaeological record. In this ideal, the organization of artifacts in the archaeological record *directly reflects* that in the behavioral domain, unaffected by extra-activity cultural formation processes (e.g., storage, curation) or natural formation processes—what Binford (1981) has termed a "Pompeii effect." However, the unexpected and expected forms of organization dealt with here differ in two ways from those described by Binford. 1) The "expected" form of organization of the archaeological record is not *absolute* in nature. It can be any of the *various* models of artifact organization presented above, thought of as a baseline organization of artifacts in the behavioral domain. 2) The concept of "unexpected" absences is used here simply as a *heuristic device* to clarify the differences in artifact organization that can distinguish the behavioral and archaeological domains. The reader is asked to view the archaeological record *as if* he were unaware of the effects of extra-activity cultural formation processes and natural formation processes and as if he thought archaeological artifact organization directly reflected behavioral artifact organization, in order to clarify the effects of those processes.

The unexpected absences in each of the five least constraining models (Models 2-6) in Figure 4 vary in their placement so as to produce five different organizational forms. The forms differ from each other and from Model 1 in whether they encompass global asymmetry, variation in the magnitude of local asymmetry, variation in the direction of local asymmetry, and/or whether some groups of artifacts totally lack some expected types (the four aspects of asymmetry variation listed in Table 2).

Now consider any two or more of the five least constraining models as representing archaeological records that have been derived from the behavioral domain as modeled by some less constraining model. The specific placements of unexpected absences in the models that represent the archaeological records, which define the specific differences between them in aspects of asymmetry, can then be attributed to and linked to the kinds, numbers, and intensities of the formation processes that generated them and that determine alterations between the behavioral and archaeological domains.

1) Kinds of formation processes. Assume a Model 1 or 2 form of organization of artifact types among events in the behavioral domain. If the formation processes responsible for a set of archaeological deposits within a site are of a kind likely to have acted *uniformly* over all events or deposits in the site, producing the same number of unexpected absences of the same kinds of artifacts in each locale, then asymmetry between the types will probably be of constant local magnitude and direction from deposit to deposit (Model 2). Table 4 lists several specific formation processes that tend to act in this manner. If the formation processes are apt to have acted *disuniformly* among events or deposits in the site, creating different numbers of unexpected absences of the same kinds of artifacts in different locales, then asymmetry between types among deposits will likely vary locally in magnitude, at least, and perhaps in direction (Models 3, 4, 5, or 6). Processes of this kind are much more common (see Table 4).

2) Number of formation processes. The greater the number of formation processes that are responsible for an archaeological record and that act differentially over space, the greater is the chance that some of the processes will not be spatially correlated. This will produce different numbers of unexpected absences of both the same and different kinds of artifacts in different locales, creating variation among deposits of a set in the direction as well as the magnitude of asymmetry between their artifact types (Model 4, 5, or 6).

3) Intensity of formation processes. The greater the intensity of a formation process that acts differentially over space, the greater is the likelihood that unexpected absences of the artifact type it affects will be taken to the extreme circumstance in which some deposits of a set lack the type completely (Model 5).

4) Number and intensity of formation processes, combined. As the number of formation processes that act differentially over space increases and their intensity increases, it becomes more probable that unexpected absences of several artifact types will be taken to the extreme circumstance in which some deposits of a set lack one or more of the types completely and the missing type(s) vary locally (Model 6).

In sum, systematic relationships can be found between the form of organization of artifact types within a set of archaeological deposits (as described by the models in Fig. 4 and Table 2) and the kinds, numbers, and intensities of the formation processes responsible for them.

In relating different kinds of formation processes to different models of artifact organization, the above framework considers only a general distinction: that between processes which tend to act uniformly over events or deposits vs. those which tend to act disuniformly. It also is possible, however, to associate *specific* kinds of formation processes (e.g., curation rates, various post-depositional processes, recovery bias, artifact classification bias) with specific models. Such linkages, however, are more easily expressed in mathematical terms and from the perspective of the techniques appropriate for analyzing data in the form of the models. Consequently, this discussion must await the introduction of such techniques and is given later (pp. 359-373).

Finally, it is possible to specify, to some extent, which models of archaeological organization are more likely to typify archaeological records in general. This can be done on the basis of the relative number of existing formation processes that act disuniformly as opposed to uniformly over events or deposits (Table 4). Given that most formation processes tend to act disuniformly over events or deposits, one can expect that many archaeological records will have artifact organizations similar to Models 3, 4, 5, or 6. This conclusion partially supports Carr's (1984) previous concern for the globally or locally polythetic organization of the archaeological record and the congruence of spatial analytic techniques to these forms of organization.

Processes Leading to Forms of Organization in the Archaeological Domain: The Nonoverlapping-Overlapping Dimension

The greater variation in relationships between artifact types that can arise, as they are transferred from the behavioral domain to the archaeological and then altered in the archaeological domain, can be described not only by the sequence of less and less constraining models of organization along the monothetic-polythetic dimension. A sequence of less constraining models of organization along the nonoverlapping-overlapping dimension also describes this transformation. Given either a nonoverlapping or overlapping baseline organization of artifact types between different sets of events in the behavioral domain, there will be a tendency for sets of deposits in the archaeological domain to be overlapping or to overlap more. This difference can result from the operation of any of several different kinds of cultural and natural formation processes (Table 5). The probability of occurrence of overlap or the increase in amount of overlap between sets of deposits will depend on the intensity with which those processes occur and/or the number of them that occur.

LINKING THE MODELS OF ORGANIZATION WITH SPATIAL ANALYTIC TECHNIQUES

In this section, quantitative techniques of spatial analysis that make assumptions that are congruent with the structure of the twelve models of artifact organization within the behavioral and archaeological domains will be specified and described. This linkage represents the final step in the development of a series of entry models, each of which is comprised of a model of artifact organization, the formation processes capable of generating that organization, and the spatial techniques assuming that form of organization.

Two broad approaches to defining the relationships between artifact types within a site are possible, only one of which is considered here. The first focuses on artifact types as pairs, and whether their arrangements are significantly similar or different in a statistical sense. Some procedures used in this manner include: significance tests for Pearson's correlation coefficient *r* (Olkin, 1967) and Kendall's rank correlation coefficient *tau* (Kendall, 1955), the X^2 test of independence using Yates continuity correction and mean or median split procedures (Dacey, 1973; Pielou, 1969), and segregation analysis (Pielou, 1964). Carr (1984) summarizes many of these procedures and their different assumptions, and references examples of their use on archaeological data.

The second approach to defining relationships between artifact types focuses on simultaneous relationships between multiple artifact types. It involves two steps. First, the degree of coarrangement of each artifact type with each other type is expressed with any of a number of "similarity coefficients," such as a Jaccard or correlation coefficient or an average intertype nearest neighbor distance. Then, a higher-level pattern-searching algorithm is applied to the matrix of coefficients for all possible artifact type-pairs in order to reveal groups of one to multiple artifact types that are more similar to each other in their spatial arrangement than they are to artifact types in other groups. The many varieties of factor analysis and cluster analysis are examples of such algorithms.

These two approaches can be used together to give a fuller understanding of one's data, the pairwise tests preceding the multitype analyses. However, in this chapter, only methods of multitype analysis will be discussed, with emphasis on similarity coefficients rather than higher-level algorithms.

General Perspective

The two steps of multitype spatial analysis—measurement of the degree of coarrangement of each pair of artifact types and definition of groups of similarly arranged types—require different sets of methods that make assumptions about different aspects of artifact organization. Measures of similarity, which are used in the first step, vary in their assumptions about form of organization along the monothetic-polythetic dimension (Table 6). Higher-level pattern-searching algorithms, which are used in the second step, vary in their assumptions about form of organization along the nonoverlapping-overlapping dimension (Table 7).

It is possible to order available coefficients for measuring similarity into a sequence according to the restrictiveness of their assumptions about artifact

Table 13.6

Similarity Coefficients Appropriate for Analyzing Spatial Arrangements of Artifact Types Having Various Forms of Organization along the Monothetic-Polythetic Dimension

Form of Organization	*Appropriate Coefficient For Item Point Location Data*	*Appropriate Coefficient For Grid Cell Data*
Model 1*	AVDISTM (this chapter; Carr, 1984)	—
2	—	Pearson's r
—	—	Kendall's tau and tau-b (Kendall, 1955), partially. Goodman and Kruskal's gamma (Goodman & Kruskal, 1963, p. 322), partially. Spearman's rho (Kendall, 1955), partially.
3	—	—
4	AVDISTLP1 (this chapter; Carr, 1984)	Jaccard similarity coefficient (Sneath & Sokal, 1973), Cole's C_7 (Cole, 1949), Hurlebert's C_8 (Hurlebert, 1969)
5	AVDISTGP (this chapter; Carr, 1984)	—
6	AVDISTLP2 (this chapter)	—

*Models shown in Fig. 3 and described in Table 2.

Table 13.7

Higher-Level Pattern-Searching Algorithms Appropriate for Analyzing the Spatial Arrangement of Artifact Types Having Nonoverlapping or Overlapping Set Organization*

Only Nonoverlapping Sets Constructed	*Overlapping or Nonoverlapping Sets Constructed*
1. standard polythetic agglomerative clustering routines (Sneath & Sokal, 1973; Anderberg, 1973; Hartigan, 1975)	1. R-mode or Q-mode factor analysis (Rummel, 1970; Davis, 1973)
2. interval scale matrix ordering (Hole & Shaw, 1967; Craytor & Johnson, 1968; Cowgill, 1972; Marquardt, 1978)	2. multidimensional scaling (Kruskal & Wish, 1978)
	3. cluster routines by Jardine and Sibson (1968); Cole and Wishart (1970); for small numbers of observations only
	4. ADCLUS least squares clustering procedures (Shepard & Arabe, 1979; Sarle, 1981; Arabie et al., 1981)
	5. ITREG (Darden, 1982)
	6. OVERCLUS (Carr, this volume)

*All algorithms may operate on each kind of similarity coefficient listed in Table 6, except factor analysis, which strictly must operate only on positive semidefinite matrices to obtain standard interpretations of generated statistics.

organization along the monothetic-polythetic dimension, i.e., according to the spatial relationships that are required to occur between two types for them to be considered coarranged by the measures. This sequence can be coupled with the sequence of organizational models, which similarly stipulate the relationships that are minimally required among types for them to be interpreted as a set. Thus, the models of organizational variation along the monothetic-polythetic dimension can be linked to mathematical measures appropriate for the analysis of data sets that are similar to the models (Table 6). Likewise, the several algorithms available for defining multitype groups can be ordered into two classes, according to whether they are restrictive and assume nonoverlapping structure or are more permissive and allow overlapping structure. This dichotomous sequence is paralleled by variation in the organizational models along the nonoverlapping-overlapping dimension, again allowing model data structures to be coupled with the techniques appropriate for the analysis of data of such forms (Table 7).

The coupling of a sequence of models of artifact organization and a sequence of techniques is helpful not only in meeting the aims of this chapter; it also makes clear certain areas of *technical deficiency* that require correction. First, only one of the models of organization along the monothetic-polythetic dimension has congruent measures of similarity allowing analysis of data in *either* item point location or grid cell format (Table 6). The fact that some models lack similarity measures useful in analyzing data of certain formats—particularly grid cell data—is critical. Most descriptions of archaeological sites record artifact proveniences in a grid cell format rather than a point location format. Often the mesh of the grid is too coarse for the data to be transformed into an approximate point location form that might be analyzed with point location similarity coefficients. Second, there appear to be no similarity coefficients, based on either grid cell or item-point location data, that are strictly concordant with the form of organization posed in Model 3.

The following sections detail the mathematical procedures of some of the measures and methods listed in Tables 6 and 7. They also expand upon the data organizational assumptions of the techniques in behavioral terms, and discuss the linkages between *particular* formation processes, models of organization, and techniques, which could not be presented earlier. The discussions of the similarity coefficients AVDISTM, AVDISTLP1, AVDISTGP, and AVDISTLP2 represent an elaboration and segmentation of the method called polythetic association (Carr, 1984) into several alternative techniques. Discussion will begin with the measures of similarity and proceed to the higher-level pattern-searching algorithms.

AVDISTM

A simple statistic that compares the arrangement of items of two artifact types is AVDISTM: the average absolute distance between items of one type and their nearest neighbors of the second type. A *base type* and *reference type* are chosen. For each item of the base type, the Euclidean distances at which surrounding items of the reference type occur are compared until the nearest neighbor of the reference type is found. The same procedure is then repeated, this time using the items of the reference type as base points and the items of the base type as the satellite reference points. The average intertype distance can be computed by

$$\mathrm{AVDISTM}_{AB} = \frac{\sum_{1}^{n}\overline{AB} + \sum_{1}^{m}\overline{BA}}{n + m} \tag{2}$$

where n is the number of items of type A, m is the number of items of type B, $\overline{AB}$ is the distance from a given base item of type A to its nearest neighbor of type B, and $\overline{BA}$ is the distance from a given base item of type B to its nearest neighbor of type A. Note that the number of $\overline{AB}$ distances n and their sum need not be equal to the number of $\overline{BA}$ distances m and their sum. This depends on whether the number of items of type A and B over a site are equal and symmetrically arranged.

A computer program (POLYTHETIC1) for calculating AVDISTM and other coefficients for multiple pairs of artifact types is provided in Appendix A.

AVDISTM measures the degree of similar arrangement of artifacts of two types relative to the organizational standard characterized in Model 1 (Fig. 4, Table 2). Two artifact types are assumed to have a similar distribution only when they are arranged in a symmetric manner in a 1:1 proportion, both globally and locally. If two artifact types are coarranged such that items of one type are usually close to items of the second type and *vice versa*, both of the sums of distances, $\Sigma\overline{AB}$ and $\Sigma\overline{BA}$, will be small. AVDISTM will be small, indicating that the two types are coarranged. However, if two artifact types are coarranged, but in an asymmetrical manner (similar distributions, different densities; e.g., Model 2, Fig. 4) such that sometimes the less dense type is not close to the more dense type, then one of the sums of distances, $\Sigma\overline{AB}$ or $\Sigma\overline{BA}$, will be large—whichever represents the sum of distances from items of the more dense type to items of the less dense type. Consequently, AVDISTM will be inflated. The coefficient will erroneously indicate that the two types are less coarranged than they really are because it judges asymmetry between types, and "unexpected absences" of items of one type from the vicinity of items of another, as a form of dissociation.

Linkage of Model 1 and AVDISTM to behavior and site formation processes. Model 1 is an appropriate organizational standard and AVDISTM is a correspondingly appropriate measure of the coarrangement of types only when certain rigorous conditions, regarding past behavior and site formation processes, are met.

1) Usually, artifacts of types within the same activity set in the behavioral domain must have been distributed among events in the globally and locally symmetric manner shown in Model 1. Alternative tool types capable of accomplishing the same ends in different episodes of an activity type must not have been employed.

2) The artifacts must have been deposited expediently at their locations of use or in the same refuse dumps. If not deposited expediently, then artifact types in the same activity set must have had equivalent discard rates and all activity areas and refuse dumps within which they were deposited must have been used over an extended time, allowing the proportions of types within such locations to approach stable, 1:1 ratios over time.

3) The artifacts must have remained at their locations of deposition, unaffected by the numerous post-depositional processes that can cause "unexpected absences" of an artifact type (Table 4), until the time of excavation.

4) Artifacts must have been recovered completely and classified to function

correctly, again preventing "unexpected absences." Only if these conditions are true will the artifact types in the same depositional set, representing an activity set, be organized in the form that is stipulated by Model 1 and required by AVDISTM for them to be defined as one set.

Ratio and Rank-Scale Correlation Coefficients

Measures that assess the degree of similar arrangement of artifact type-pairs relative to organizational standards that are less constraining than Model 1 include a variety of ratio and rank scale correlation coefficients applicable to grid cell count data.

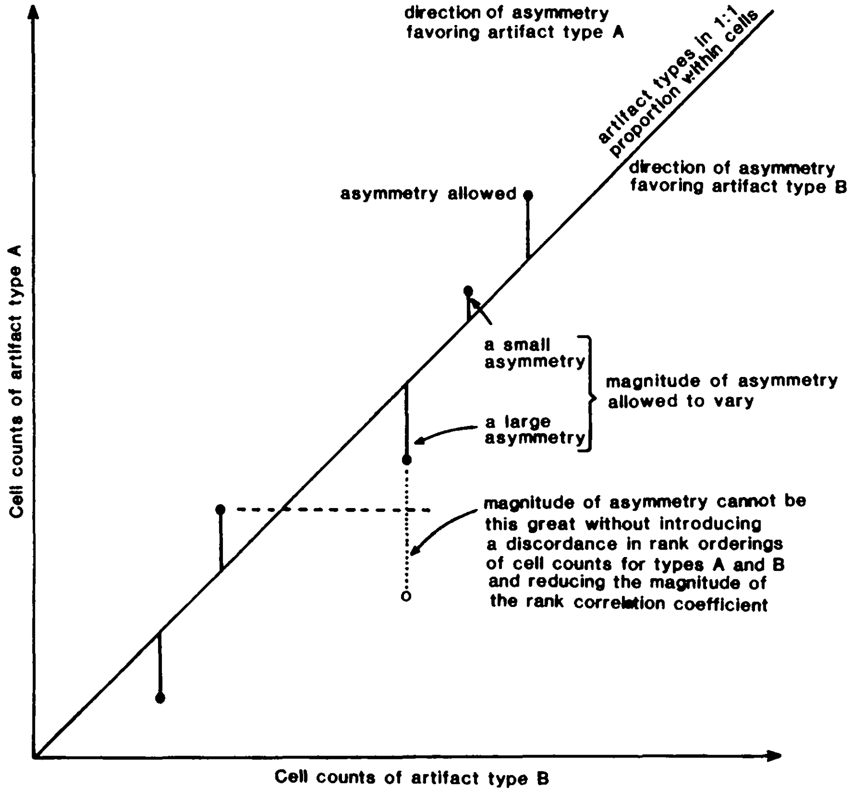
Pearson's product-moment correlation coefficient, r. This coefficient can be used to measure the degree of covariation among densities of two artifact types within grid cells. It obtains its highest value (+1), indicating perfect coarrangement of two types, when in every cell the *proportion* of artifacts of the two types is some constant; i.e., the data are consistent with Model 2.

Rank correlation coefficients. These measures include Kendall's *tau* and *tau-b* (Kendall, 1955; Nie et al., 1975, p. 227), Spearman's *rho* (Kendall, 1948), and Goodman and Kruskal's *gamma* (Goodman & Kruskal, 1963, p. 322; Nie et al., 1975, p. 228). They are somewhat more permissive than Pearson's *r*. They allow greater variation in the relationships between types within cells before their degree of coarrangement is judged less than perfect, but not to the extent implied by Models 3 or 4, where simply the co-occurrence of types is required. In particular, rank correlation coefficients measure the degree of concordance in two separate rank orderings of grid cells: one by their counts of one artifact type, and a second by their counts of a second type. The coefficients reach their greatest value, +1, which indicates perfect coarrangement of two types, when the concordance of the orderings is perfect, i.e., the cells with the first, second, and third highest counts for one artifact type also have the first, second, and third highest counts of the second type, and so on. The proportions of artifact types within cells can vary within restricted ranges without decreasing the value of the coefficients from that indicating perfect coarrangement. Minor local changes in the magnitude and direction of asymmetry between types from cell to cell are permitted, but not to the extent allowed in Models 3 and 4, which will result in discordances among the rank orderings (Fig. 6). Moreover, a monotonic relationship between the ranked number of items of each type within cells is still required, as in Model 2 and unlike in Models 3 and 4.

The different measures of rank correlation vary in how the degree of concordance between rank orderings of grid cells for two types is calculated. Kendall's *tau*, Spearman's *rho*, and Goodman and Kruskal's *gamma* do not discount the effect of tied cell rankings, which tends to inflate their values, whereas Kendall's *tau-b* reduces this distortion and seems preferable (Hietala & Stevens, 1977, p. 549). Also, Kendall's *tau* considers only the correct or incorrect *placements* of grid cells in the two ranked orderings of them, relative to perfect concordance; in contrast, Spearman's *rho* considers the *magnitude of displacements* of grid cells in the two orderings from a perfectly concordant order. Thus, Spearman's *rho* is more sensitive than Kendall's *tau* to large changes in the magnitude and direction of asymmetry between types from cell to cell which cause discrepancies in rank orderings (Fig. 6).

When using Pearson's *r* or any of the rank correlation coefficients, the size, shape, orientation, and placement of cells within the grid system must agree with the predominant size, shape, orientation, and placement of clusters of artifacts, if the values of these measures are to accurately represent the degree of coarrangement of types. The specific effects resulting from discrepancies between grid cell characteristics and cluster characteristics have been summarized by Carr (1984). To overcome these effects, *dimensional analysis of variance*

Fig. 13.6. Rank correlation coefficients allow minor local changes in the magnitude and direction of asymmetry between artifact types in a set to occur from grid cell to grid cell of a study area, without affecting the measures. Large variations in the magnitude and direction of asymmetry implied by Model 3 and Model 4 kinds of organizations are not permitted.



(Grieg-Smith, 1961, 1964; Kershaw, 1964) or *Morisita's method* (Morisita, 1959, 1962) can be used prior to correlation analysis. These methods allow counts within grid cells to be grouped into counts within blocks approximating the size, shape, and orientation of clusters. However, an approach preferable to using dimensional procedures followed by correlation on grouped data is *dimensional analysis of covariance* (Kershaw, 1960, 1961). The procedures for these methods and the limitations of their application to archaeological data are summarized by Carr (1984, pp. 144-154, 166-170) and Whallon (1973).

Linkage of Model 2 and Pearson's r to behavior and site formation processes. Model 2 is an appropriate standard of the relationships between coarranged artifact types, and Pearson's r is a correspondingly appropriate measure of coarrangement relative to that standard, under conditions almost as rigorous as those required of AVDISTM.

1) Artifact types used together as an activity set must have been used at all locations of activity in similar proportions, such that their frequencies covaried.

2) The artifacts must have been deposited expediently at their locations of use or in the same refuse dump.

Alternately, 1) artifact types in the same activity set must have had constant discard rates and 2) all areas of their deposition must have been used over an extended period of time, allowing the proportions of the types within such areas to approach some stable ratio over time.

3) In either case, post-depositional processes causing "unexpected absences" of an artifact type can have occurred, but are limited to those causing absences in equal frequency over all locations of deposition (Table 4, uniform processes). Only these processes will preserve some constant set of proportions between artifact types in the same activity set.

4) Incomplete recovery processes or misclassification processes causing unexpected absences of artifact types must have operated in such a way that absences are distributed in equal frequency over all locations of deposition (seldom true), for the same reason as in point 3.

Jaccard's and Cole's Similarity Coefficients

The degree of simple co-occurrence of two artifact types can be measured with a number of association coefficients that are based on grid cell distribution data organized in the form of a two-way contingency table. The two dimensions of the table represent the "presence" or "absence" of each type within any given grid cell. Presence and absence states can be defined in the usual manner for types occurring in sparse numbers in a few or moderate number of grid cells. Alternatively, they can be defined so as to represent a high-and-low cell count dichotomy made in reference to some count threshold value such as the mean (Dacey, 1973) or median (Pielou, 1969; Hietala & Stevens, 1977)—an approach useful for types having a greater range of cell counts and a more ubiquitous distribution. Among the most commonly used association coefficients calculated from data in this format are the *simple matching* coefficient, the *Jaccard* coefficient, and indices of *Dice, Bray,* and *Yule* (Sneath & Sokal, 1973).

The various association coefficients differ in the weights they attach to the a, b, c, and d cells of the contingency tables used in calculating them, and thus, are appropriate under different circumstances. Of relevance here is the weight given to the d cell in contributing to the association of the two dimensions. When the two levels of each dimension of the contingency table represent alternative attribute states of observations, one state of which *must occur* for each observation (e.g., dark hair/light hair; dark eyes/light eyes), then the matches of the d cell should count toward the association of the two dimensions. In contrast, when the two levels of each dimension represent the presence or absence of a characteristic which *need not or can not occur* for each observation, then a coefficient that omits consideration of negative matches is desirable: one is interested in the relative frequency of joint occurrences or single occurrences of the characteristics in only those observations that have one or more of them (Cole, 1949; Sneath & Sokal, 1973, p. 131).

Intrasite spatial data tabulating the presence or absence of artifact types within grid cells, where each type represents a characteristic that need not occur in all observations (cells), are of the latter form. Thus, they are appropriately analyzed only with coefficients that do not allow negative matches to contribute to association. One coefficient that accomplishes this requirement is the Jaccard coefficient

$$J_{xy} = \frac{a}{a + b + c} \tag{3}$$

where a, b, and c are the values of the a, b, and c cells in the contingency table for artifact types x and y. Other coefficients are *Cole's* C_7 (Cole, 1949, p. 423) and a more general and sometimes preferable form of it, *Hurlbert's* C_8 (Hurlbert, 1969).

Like the application of ratio and rank scale correlation coefficients, the application of association coefficients to archaeological data assumes that the size, shape, orientation, and placement of the grid cells within which the artifact distributions are framed are appropriate compared to these same spatial characteristics for artifact clusters. Deviation of grid cells from artifact clusters in these characteristics bias the association coefficients as measures of coarrangement in ways analogous to those in which the correlation coefficients are biased (Carr, 1984).

Jaccard's, Cole's, and Hurlbert's coefficients measure the degree of similar arrangement of artifacts of two types relative to the organizational standards characterized in Model 4. The measures obtain their highest value (+1), which indicates perfect coarrangement of two types, when both types simply *occur* jointly in the same grid cells and deposits, regardless of the magnitudes or directions of asymmetry between the types. The coefficients have less stringent requirements for assessing coarrangement than those stipulated by Model 3, which assumes that two types are coarranged only if they both occur together and maintain the same direction of asymmetry from cell to cell or deposit to deposit. There currently are no standard measures of association that assume the kind of organization expressed in Model 3, although this kind of data structure is not idiosyncratic to archaeology (Pielou, 1964).

Linkage of Model 4 and association coefficients to behavior and site formation processes. Association coefficients that are concordant with the form of organization in Model 4 are appropriate measures of the relationships between artifact types under conditions more typical of the archaeological record.

1) Even assuming that activity areas and their associated refuse dumps were used only a short period of time (an assumption leading to the most restrictive set of conditions to be discussed here), it is only necessary that artifact types in the same activity set were always used together; the proportions in which they were used need not have been constant.

2) The artifacts must have been deposited expediently in their locations of use or discard such that artifact types used together also occur together archaeologically. If the effects of differential breakage rates and curation rates or other formation processes have caused different subsets of the activity set to be deposited at different locations of its use, lower associations will be found between the artifact types; their membership in one activity set may not be apparent.

3) Only one representative of each artifact type that is deposited in the activity areas or associated dumps need have remained there and/or have been recovered and classified correctly. Whereas *any* amount of spatially nonuniform post-depositional disturbance, incomplete recovery, or misclassification of artifacts within deposits will distort the proportions of types within them—affecting the ratio scale correlation coefficient and the AVDISTM measure of coarrangement—these same processes can proceed in a nonuniform manner to a *considerable* degree without affecting the pattern of presence or absence states of types among deposits. The degree to which these processes can proceed for an artifact type is inversely related to its original frequency of deposition.

If activity areas and their associated refuse dumps were used over an extended period of time, even less constraining conditions are required for the appropriate application of association coefficients. As an alternative to condition 1, above, artifact types in an activity set can have been distributed in a globally polythetic manner among events and areas of use or deposition (i.e., as in Model 5 or 6). (This might result from some of the types having been alternative or optional tool forms.) In such conditions, the repeated use of the work areas or dumps will have caused the presence-absence states of each type in the activity set within each of the several locations to tend toward presence over time. This represents one circumstance in which the organization of artifact types in the behavioral domain is atypically *less constraining* than their organization in the archaeological domain.

As an alternative to condition 2, above, artifacts need not have been deposited expediently within activity areas or associated dumps, and types can have had variable discard rates. Again, repeated use of the locations will have increased the probability, over time, that all types within the activity set were deposited in each location and co-occur.

AVDISTLP1, AVDISTGP, AVDISTLP2

Measures of coarrangement that are concordant with Models 4, 5, or 6 and applicable to item point location data can be derived through modifications of the AVDISTM statistic. Central to each of the derivations is a key argument related to the goal of designing measures that are insensitive to *asymmetry* among artifact types or changes in its *magnitude* from place to place within a study area—the common denominators of the three models. The argument is as follows:

Suppose that two artifact types are coarranged within an area, but in an asymmetric manner. Items of the more densely distributed type will always occur in the neighborhoods of items of the less densely distributed type, but not vice versa; i.e., there will be "unexpected absences" of the less densely distributed type in certain locations of the more densely distributed type (Fig. 5c). Under these circumstances, the two sums of intertype distances $\Sigma\overline{AB}$ and $\Sigma\overline{BA}$, which were defined previously (pp. 359-360), will not be equal. The distances from items of the rarer type to items of the more common type will generally be small, as will their sum, because items of the rarer type usually are surrounded by items of the more common type. These distances and their sum will accurately indicate the degree of coarrangement of types under the assumption of permissible asymmetry relations, because they *ignore the "unexpected absences"* of the rarer type in some locations of the more common type. In contrast, the distances from items of the more densely distributed type to items of the less densely distributed type will sometimes be large, and their sum will be large, because items of the more common type are not necessarily surrounded by items of the rarer type. These distances and their sum will not accurately measure the degree of coarrangement of types under the assumption of permissible asymmetry relations, because they reflect the unexpected absences of items of the rarer type from the neighborhods of some items of the more common type. For example, in Figure 5c, type X and O are coarranged under the assumption of permissible asymmetry relations. The distances from type X (the rarer type) to type O (the common type) are all small, ignore the unexpected absence of an item of type X from the item of type O in the upper right hand corner, and accurately estimate the degree of coarrangement of the two types under the assumed form of organization. The distances from type O to type X, on the other hand, are sometimes small but sometimes large, consider any unexpected absences of type X from the vicinity of type O, and do not necessarily estimate the degree of coarrangement of the two types accurately.

To design a measure of coarrangement that is analogous to AVDISTM but unaffected by the asymmetrical form of arrangement of artifact types within a given area, it should be clear from the above that it is necessary to consider only those distances from items of the more common type to items of the rarer type. This can be achieved by calculating *two* average inter-item distances

$$\text{AVDIST1} = \frac{\sum_{1}^{n} \overline{AB}}{n} \qquad \text{AVDIST2} = \frac{\sum_{1}^{m} \overline{BA}}{m} \tag{4}$$

and choosing the *minimum* of the two as the measure of coarrangement of the two types:

$$\text{AVDIST} = \min(\text{AVDIST1}, \text{AVDIST2}) \tag{5}$$

High values of AVDIST, which indicate dissociation of two artifact types, will occur only when both types are *mutually distant* from each other.

By measuring the degree of coarrangement of two artifact types in this manner, it thus is possible to isolate two kinds of absences of an artifact of one type from the neighborhood of an artifact of another—the two kinds of absences having different *causes*. These are 1) *mutual* absences due to the *actual dissociation* of the types from each other and reflecting their belonging to different depositional sets, and 2) *unexpected asymmetrical* absences that indicate only the asymmetrical form of distribution of artifact types and that result from any of the *formation processes* listed in Table 4.

Note that the statistic, AVDIST, is insensitive not only to the asymmetrical form of coarrangement of two types, but also to local differences in the magnitude of the asymmetry. The average distance from items of the rarer type to items of the more common type—the chosen measure of coarrangement—is unaffected by whether items of the rarer type are missing from the vicinity of *few or many* items of the more common type in any given portion of the study area. Only the *ignored* average distance, from items of the common type to items of the rare type, is affected by the frequencies of unexpected absences and the magnitudes of asymmetry within subareas.

Three similarity coefficients—AVDISTLP1, AVDISTGP, and AVDISTLP2—which measure the degree of coarrangement of types relative to the different organizational standards posed in Models 4, 5, and 6, respectively, can be constructed. This can be achieved by 1) applying the procedure for partitioning intertype distances to areas of different scale, and 2) stipulating how the complete absence of a type from a cluster of artifacts should be handled.

Constructing AVDISTLP1. AVDISTLP1, a "locally polythetic average intertype nearest neighbor distance coefficient," is designed to be congruent in its assumptions with the organizational requirements for coarrangemnt that are specified by Model 4. Model 4 allows the asymmetry relations occurring between two coarranged artifact types to vary in direction and magnitude from artifact cluster to artifact cluster. However, it requires that each cluster contain at least one of the artifact types—that asymmetry in any cluster not be taken to the extreme case in which one of the types is completely absent from it (Table 2).

AVDISTLP1 allows the direction of asymmetry between two coarranged artifact types to vary from cluster to cluster by partitioning intertype distances locally, *within each cluster.* If $\mathrm{AVDIST1}_j$ and $\mathrm{AVDIST2}_j$ represent the partitioned average distances between items of two types A and B within cluster j having n_j items of type A and m_j items of type B, and if

$$\mathrm{AVDIST1}_j = \frac{\sum_{1}^{n_j} \overline{AB}}{n_j} \qquad \mathrm{AVDIST2}_j = \frac{\sum_{1}^{m_j} \overline{BA}}{m_j} \tag{6}$$

then a measure of the asymmetrical coarrangement of the two types within cluster j can be defined as:

$$\mathrm{AVDIST}_j = \min(\mathrm{AVDIST1}_j, \mathrm{AVDIST2}_j) \tag{7}$$

The degree of coarrangement of the two types over the study area at large can be defined as the average of the AVDIST_j statistics, weighted in accordance with the number of distances, x_j (either n_j or m_j), used to calculate them:

$$\mathrm{AVDISTLP1} = \frac{\sum_{j=1}^{k} (x_j)(\mathrm{AVDIST}_j)}{\sum_{j=1}^{k} (x_j)} \tag{8}$$

By default, the statistic is congruent with Model 4's stipulation that the magnitude of asymmetry between coarranged artifact types be allowed to vary from artifact cluster to cluster; each intracluster measure of coarrangement, AVDIST_j is insensitive to the magnitude of asymmetry within the cluster.

AVDISTLP1 is made congruent with the final requirement of Model 4—that each cluster contain at least one artifact of each type for two types to be considered perfectly coarranged—by adhering to a second stipulation in calculating the statistic. If within any cluster j only one of the two types under consideration is present, then the measure of coarrangement of the two types for that cluster, AVDIST_j, is defined as the average distance from items of the type present in the cluster to nearest items of the missing type in *any other cluster.* These *intercluster* distances, of course, will be large giving a large value to AVDIST_j and increasing the value of AVDISTLP1 proportionally. As more and more clusters completely lack one of the two types, interpretable as less similar arrangement of the types under the assumptions of Model 4, more of the AVDIST$_j$ statistics will become large in value and AVDISTLP1 will appropriately become greater, indicating generally greater distances between items of the two types.

The procedures just presented assume three restrictive conditions of the data to be analyzed. 1) The spatial distribution of each artifact type exhibits clusters. 2) The clusters are spatially discrete and uniquely definable. 3) Clusters are the proper natural units between which asymmetries among artifact types should be allowed to vary in direction. The last assumption is valid if the processes responsible for local variation in the direction of asymmetry relations are the same cultural formation processes that were involved in artifact deposition and cluster generation. The assumption is invalid if the processes that caused asymmetry variation are post-depositional disturbance or recovery processes which could have operated on different spatial strata that crosscut clusters.

Some of these constraints can be relaxed if additional analytic steps are taken. 1) Suppose that clusters of artifacts are apparent within the distributions of each type but overlap mildly such that the cluster membership of relatively few items is uncertain (e.g., as in the Pincevent example, below). Also suppose that major changes in the direction of asymmetry between types do not occur within clusters, suggesting that clusters—rather than other strata crosscutting clusters—are reasonably proper units between which asymmetries among types should be allowed to vary in direction. In these circumstances, it is possible to draw *approximate* boundaries between the clusters and then to calculate within-cluster AVDIST$_j$ statistics that are nevertheless meaningful, using the following additional algorithmic procedure. If an item of type X has its nearest neighbor of the opposite type O *outside* the cluster j to which the item of type X is assigned (indicating a misdrawn boundary), then *that* nearest neighbor distance, rather than some spuriously larger one to a nearest neighbor of type O within the cluster, should be used to calculate the average distance from type X to type O in cluster j. In this way, the approximate method by which the boundaries between clusters are drawn and by which the item-membership of each cluster is determined does not artificially inflate the AVDIST$_j$ statistics and AVDISTLP1. Also, clusters can be retained as the natural units within which asymmetries between artifact types are allowed to vary, even though cluster boundaries are uncertain—a desirable circumstance.

2) An alternative approach can be taken if the data are more problematic in any of three ways: (a) if clusters are ill-defined, with wide artifact density gradients between the cores of clusters, making the cluster membership of many peripheral items unclear; (b) if clusters are not apparent at all; or (c) if clusters do not appear to be appropriate units between which artifact types should be allowed to vary in their asymmetries, based on knowledge of the formation and recovery processes for the site. The approach involves the following procedures. For any pair of types under consideration, the local relative densities of the two

types within the neighborhood of each item of either type is calculated. The radius of the neighborhood used to calculate local relative densities should be much less than that expected of any clusters that might occur in the data, but large enough to include at least several items of either type. A map of the local proportional densities of the two types then is made, which documents spatial variation in the direction of asymmetry between them (proportional densities greater than 1 or less than 1). This map can be used to define larger zones that are relatively homogeneous in the direction of local asymmetry between the types and within which AVDIST$_j$ statistics can be calculated meaningfully. AVDISTLP1 thus can be determined and the data can be analyzed in accordance with the stipulations of Model 4. Of course, if larger zones homogeneous in the asymmetry of the two artifact types are not defined by the resulting map, analysis of the data using Model 4 assumptions and the AVDISTLP1 coefficients is inappropriate.

A computer program for performing the operations of finding AVDIST$_j$ and AVDISTLP1 statistics for all pairs of types within a multitype spatial data set is provided in Appendix A. The program, POLYTHETIC2, requires the stratum assignments of each item of each type to have been determined in advance, whether the strata are clusters or zones defined on the basis of directions of asymmetries between types. It also assumes that the same strata are appropriate for each artifact type pair, though there may be instances in which this assumption is not desirable and program modification is warranted.

Constructing AVDISTGP. AVDISTGP, a "globally polythetic average intertype nearest neighbor distance coefficient," is designed to be congruent in its assumptions with the organizational requirements for coarrangement specified by Model 5. Model 5 allows the asymmetry relations between two coarranged types to vary in magnitude from cluster to cluster. It also allows asymmetry to be carried to the extreme where the rarer of the two types need not occur in some clusters, i.e., where depositional sets are globally polythetic. However, the model requires that the direction of asymmetry between the two types remain the same over all clusters—or over all locations if clusters do not exist.

All of these allowances and requirements of Model 5 can be operationalized by partitioning intertype distances into two sets globally, over the whole study area, rather than within clusters. Thus, if AVDIST1 and AVDIST2 represent the partitioned average distances between items of two types A and B within a study area having n items of type A and m items of type B, as in equation 4, then

$$\text{AVDISTGP} = \min(\text{AVDIST1}, \text{AVDIST2}) \tag{9}$$

defines the desired measure of coarrangement.

How AVDISTGP assumes the uniformity of asymmetry relations between two types over all clusters of artifacts or locales within a study area is apparent from the global manner of definition of the two kinds of average intertype distances, AVDIST1 and AVDIST2, and the choice of one of these global statistics as AVDISTGP. Suppose a study area is divided into strata representing clusters or areas of homogeneous asymmetry relations. The operation of calculating AVDISTGP for the study area at large is equivalent to 1) defining an AVDIST1$_j$ statistic and AVDIST2$_j$ statistic for each stratum *j* within the study area such that all the AVDIST1$_j$ imply distances from the same one kind of artifact to the same other kind and all the AVDIST2$_j$ imply distances in the reverse direction, 2) picking the same AVDISTn_j statistic in all strata as if it were the minimum, and 3) averaging them. If an asymmetry reversal from the global norm occurs in any locale, the chosen AVDISTn_j will *not* be the minimum of the two AVDISTn_j statistics. The average of all the chosen AVDISTn_j statistics, equivalent to AVDISTGP, will thus be inflated compared to that which would be obtained if the asymmetry reversal did not occur; this will indicate the less-than-perfect coarrangement of the two types by Model 5 standards.

How AVDISTGP assumes that the magnitude of asymmetry between two types can vary from locale to locale within a study area also is clear. Under the assumption that the data do not have local asymmetry reversals, the minimum AVDIST*n* chosen to define AVDISTGP represents inter-item distances from the rarer to the more common artifact type in each locale. These distances are insensitive to the magnitude of asymmetry.

Finally, by extension, it can be shown that AVDISTGP does not require the rarer of two types to be present in each cluster or locale where the more common type occurs. Again, assume that the data do not have local asymmetry reversals and that the minimum AVDIST*n* chosen to define AVDISTGP represents inter-item distances from the rarer to the more common artifact type in each locale. A locale will then contribute nothing to the value of AVDISTGP if the rarer type does not occur in it and the more common type does.

A computer program for calculating AVDISTGP statistics is provided in Appendix A. The program, POLYTHETIC1, does not require stratum assignments for each item of each type as does POLYTHETIC2.

Constructing AVDISTLP2. AVDISTLP2, another "locally polythetic average intertype nearest neighbor distance coefficient," is designed to be congruent with Model 6. Model 6, like Model 4, allows the asymmetry relations occurring between two coarranged types to vary in direction and magnitude from stratum to stratum. However, it also permits some strata to not have either one type or the other.

AVDISTLP2 allows the direction of asymmetry between two coarranged artifact types to vary from stratum to stratum using the same approach as AVDISTLP1, i.e., the partitioning of intertype distances into two sets locally, within each stratum (equations 6, 7, 8). This procedure also allows the magnitude of asymmetry relations between types to vary from stratum to stratum, as discussed above.

To allow some strata to not have one of the two types without increasing the value of AVDISTLP2—the point of departure of AVDISTLP2 from AVDISTLP1—it is necessary to make only a simple modification in the second procedural rule used in calculating AVDISTLP1. If within any stratum j only one of the two types under consideration is present, then the average intertype distance for the two types in that stratum, $AVDIST_j$, is set at 0 rather than at the average distance from items of the type present in the cluster to nearest items of the missing type that occur in other clusters. In this way, the absence of items of a type from a cluster does not cause any increase in the value of AVDISTLP2. The value of AVDISTLP2 depends entirely on the degree of coarrangement of the two types within only those strata where *both* are present.

Linkage of AVDISTLP1 to behavior and site formation processes. AVDISTLP1 is an appropriate measure of the coarrangement of types under the same behavioral and site formation conditions that were specified for Jaccard's and Cole's coefficient and that are congruent with the organizational properties of Model 4.

Linkage of Model 5 and AVDISTGP to behavior and site formation processes. Model 5 is an appropriate organizational standard and AVDISTGP is a correspondingly appropriate measure of the coarrangement of types under conditions that are both more and less restrictive than those appropriate for the application of Model 4, AVDISTLP1, and the association coefficients.

1) It is necessary that artifact types within the same activity set were always used together, with the more numerous types in one event always being the more numerous types in other events.

2) Artifact types must have been deposited expediently in their locations of use.

Alternatively, 1) artifact types in the same activity set must have had discard rates that varied within restricted ranges such that the ordinal relations among the rates did not vary over time, and 2) all areas of deposition must have been used over an extended period of time, allowing those ordinal relations between the frequencies of types to have stabilized over time.

3) Post-depositional disturbance processes and incomplete recovery or misclassification processes can have totally removed some artifact types from some depositional areas. However, if more than two artifact types exhibit eradication, the areas affected must be the same for all the eradicated types. The coincidence of the affected areas for the several eradicated types is necessary if a Model 5 type of organization rather than a Model 6 type of organization is to characterize the data. This requirement implies that the processes affecting the eradication of the several types must have been spatially correlated, which in some cases may be restrictive.

Linkage of Model 6 and AVDISTLP2 to behavior and site formation processes. Model 6 is an appropriate organizational standard and AVDISTLP2 is an appropriate measure of coarrangement of artifact types under behavioral and site formation conditions that are least restrictive.

1) Artifact types in an activity set can have been distributed in a globally polythetic manner among events and areas of use or deposition (Model 5 or 6 organization) as a result of some of them having been either alternative or optional tool forms.

2) Artifacts need not have been deposited expediently in their locations of use or discard, regardless of the length of time the areas were used. In some areas, some types within the same set can be unexpectedly absent as a result of the artifacts having been curated and the areas having been used over a limited amount of time.

3) Spatially nonuniform post-depositional disturbance, incomplete recovery, or misclassification of artifacts can have operated to a great degree in an uncorrelated manner, causing different artifact tyes within the same set to be completely missing in different areas where they might otherwise be expected on the basis of the types present in the areas.

At the same time, however, AVDISTLP2 requires the stringent condition that different activity sets (polythetically or monothetically organized) were deposited in areas that do not overlap to a *great* extent. Suppose that two different activity sets were deposited in many clusters, only a few of which overlap extensively. AVDISTLP2 will focus assessment of the degree of coarrangement of the artifact types on the few overlapping clusters where types from *both* sets are present and will ignore the larger number of areas where types from one or the other set are absent (Fig. 7). Artifact types that belong to the two different sets will spuriously be found to be similarly arranged. Slight amounts of overlap among many areas, however, will not produce such misleading results.

Higher-Level Pattern Searching Algorithms

Once the degree of coarrangement between each pair of artifact types has been measured with one of the similarity or dissimilarity measures previously described, it is possible to search for groups of multiple types having mutually similar arrangements. The algorithms in Table 7 can be used for this purpose. They essentially search for those relationships among type-pairs that are approximately *consistent* with and *reinforce* each other in suggesting that the multiple types belong to the same or different groups. The result is a matrix of *smoothed* relationships among types, which can be displayed visually as graphic representations having a *few* dimensions and in a way that the original matrix of complex relations cannot.

It is desirable that the algorithms used to find multitype sets have certain characteristics; consequently, some algorithms are preferable to others. These characteristics are as follows:

1) Control over smoothing. The degree of "inconsistency" between pairwise relationships that is ignored when "smoothing" them should be within the control of the researcher. Only some of the pattern-searching approaches in

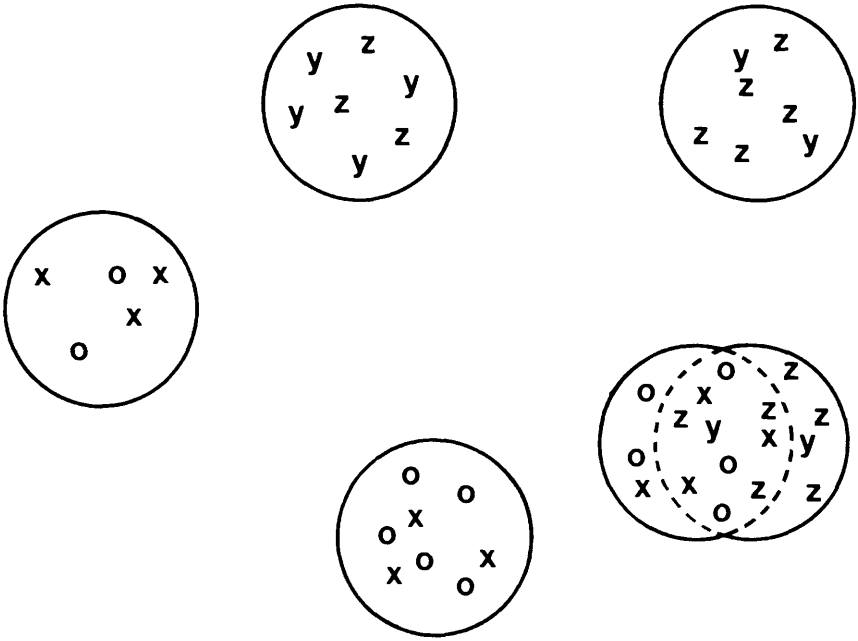


Fig. 13.7. Suppose artifact types *x* and *o* define one activity set and types *y* and *z* define another. If there is extensive spatial overlap in even just a few areas of their deposition, then AVDISTLP2 will take low values for artifact type-pairs in the different sets as well as for those in the same sets. It will spuriously indicate the similar arrangement of types in both sets. AVDISTM, AVDISTLP1, and AVDISTGP do not have this potential problem.

Table 7 allow this control. For example, when employing a polythetic agglomerative clustering approach, it is possible to choose whether a single, average, or complete linkage criterion is used to group types.[3] In an R-mode factor analytic or multidimensional scaling framework, one can choose the number of dimensions—and to some extent, the percentage of total variation in the data—to be included in displays of the data. The remaining algorithms in Table 7 do not have comparable mechanisms for controlling the degree of inconsistency that is ignored during analysis.

2) Permissible variation of structure along the nonoverlapping-overlapping dimension. The algorithm should allow groups of artifact types to be found that are overlapping, nonoverlapping, or a mixture of both forms of organization, depending entirely on the structure of the data. Table 7 lists the form of data organization, along the nonoverlapping-overlapping dimension, that is assumed by various algorithms.

3) Unnecessary a priori specification of structural parameters of the data. It should not be necessary to specify, before analysis, any vital parameters of the data's structure. The overlapping clustering approach of Jardine and Simpson (1968) and Cole and Wishart (1970) is less desirable in this manner. It requires the number of types in zones of overlap among groups to be specified (controlled by the parameter k). ADCLUS and ITREG require the number of groups of types to be known prior to analysis, and are also less preferable. The remaining algorithms in Table 7 are not constraining in this manner.

4) Concordance with similarity coefficients of many scales. The algorithm used to group types should be concordant with as wide a diversity of similarity coefficients as is possible. This trait becomes desirable when it is unclear which of a few models of archaeological organization along the monothetic-polythetic dimension is most congruent with the data at hand or when several models are congruent with different aspects of the data. Under these conditions, the data must be analyzed from several perspectives using different similarity coefficients. The several similarity matrices should be searched for multitype groups using the same pattern-searching algorithm, so that the several results are comparable.

All of the approaches in Table 7, except factor analytic ones, can be applied to matrices of any of the similarity measures described earlier. Factor analytic procedures require that the matrix to be operated on be *positive semidefinite.* This condition is met by variance-covariance matrices and correlation matrices, in relation to which principal components analysis and factor analysis were originally developed. It is also met by matrices of some other kinds of similarity measures, including the Jaccard coefficient, provided that there are no missing data (Gower, 1971, p. 860; 1966, p. 332).

Braun (1976, p. 52) has applied principal components analysis to a matrix of ϕ/ϕ_{max} coefficients numerically identical to Cole's C_7 coefficient (Speth & Johnson, 1967, p. 42), in which case the matrix of coefficients apparently was not positive semidefinite. He notes that the technique correctly extracted the eigenvectors of the matrix, but the absolute sizes of the eigenvalues did not relate algebraically to the overall variance as in the normal use of principal components analysis. Braun argues, however, the the relative sizes of the eigenvalues properly indicated the relative importance of their associated eigenvectors in describing patterning in the matrix. The use of factor analysis with various similarity coefficients is an area that needs further investigation.

5) Efficiency. The algorithm should operate efficiently, such that similarities between a large number of types can be analyzed for multitype groups in a reasonable amount of computer time. The Jardine-Sibson and Cole-Wishart overlapping clustering routines are less useful in this way. The Cole-Wishart routine—the more efficient of the two—requires an impracticable amount of time when the number of artifact types to be grouped rises above approximately 16 (Cole & Wishart, 1970, p. 162).

The particular techniques that are most useful for defining multitype clusters can vary from instance to instance with the nature of the data being analyzed. However, considering all the desirable characteristics of a pattern-searching technique simultaneously, the most broadly applicable approach seems to be multidimensional scaling, sometimes coupled with OVERCLUS. These approaches are used on the Pincevent data set examined here, and require further exposition.

Multidimensional Scaling

Multidimensional scaling (MDS) includes a very wide diversity of alternative and complementary display techniques (Schiffman et al., 1980; Kruskal & Wish, 1978; Shepard et al., 1972; Romney et al., 1972). For the purposes of this chapter, it will be assumed that the reader is familiar with many of these approaches. Attention will be focused instead on the content of justifications and bridging arguments for choosing between the various procedures in relation to the nature of intrasite spatial data. Also, some of the problems likely to arise in the multidimensional scaling of intrasite data and appropriate solutions to them will be discussed.

1) Choice of regression methods. The objective functions used to obtain an MDS representation of similarity data can be determined with classical, monotonic, or categorical least squares regression techniques (Young & Lewychyj, 1980). The first approach leads to *classical* or *metric* MDS solutions, where a specific functional relation is assumed between the similarity coefficients in the unsmoothed matrix and distances between entities in the smoothed configuration. The latter two approaches lead to *nonmetric* solutions, where the function can be any rising, monotonic relation between dissimilarities and distances.

All the similarity coefficients described above for use in intrasite spatial analysis take ratio-scale values and are amenable to either classical or monotonic MDS procedures. It is advisable in most cases to begin analysis with monotonic procedures, in order to find the appropriate number of dimensions for representing the data. Representational accuracy in the chosen number of dimensions can then be refined with classical methods.

Monotonic procedures are more helpful than classical ones in determining the proper number of dimensions for displaying data, for two reasons. (a) Classical solutions are susceptible to inflation of stress values and to unstable representations when an objective function of the wrong form is used. These conditions make it difficult for the researcher to choose the appropriate number of dimensions for data-display using either of two common criteria: the stability of representations or their interpretability. Monotonic methods, which do not require the specification of an objective function of a particular form, are not so disadvantaged (Kruskal & Wish, 1978, pp. 76-78). (b) For monotonic methods, Monte Carlo studies are available, which suggest stress values that are and are not statistically significant (Kruskal & Wish, 1978, pp. 53-56).

For some intrasite data sets, however, classical methods are likely to be preferable from the start. This is true where groups of coarranged types are few in number and nonoverlapping, and where the differences in arrangement between groups is large compared to intragroup arrangement variation, i.e., where a few compact, distant groups characterize the data. Under these conditions, monotonic procedures can produce "degenerate" solutions (Kruskal & Wish, 1977, p. 30). The number of groups and their constituent types will be correctly identified, but the relationships among groups will not be accurately described, prohibiting analysis of hierarchical patterning. The problem of degeneracy and the necessity of using classical methods to overcome it are less likely for study areas where formation processes leading to overlapping sets of deposits have operated (Table 5).

2) Choice of approaches to interpreting configurations. Configurations that result from multidimensional scalings can be examined for relationships among entities in two ways. Most commonly, interpretable *dimensions* of variability within a configuration are sought by examining variation in the attributes of the scaled entities in different directions. Regression techniques are used to determine whether the attributes thought to explain the positioning of entities in certain directions actually have statistically significant explanatory power (Kruskal & Wish, 1978, pp. 35-43). An alternative approach is *neighborhood analysis,* in which local groups of entities with similar attributes are sought (Guttman, 1965; Kruskal & Wish, 1978, pp. 43-48). Clustering techniques can be applied to matrices of Euclidean distances between the stimulus coordinates of entities to locate potentially significant clusters (see pp. 380). A variety of standard statistical procedures can be used to test whether the distributions of attributes differ significantly from cluster to cluster.

For intrasite spatial analysis, where the goal is to define groups of similarly arranged types that represent depositional sets, the neighborhood analysis approach to configuration interpretation is more appropriate.

3) Methods for exploring local structures. In intrasite spatial analysis, both global and local structure are of interest. The researcher is concerned with hierarchical relationships among groups of artifact types representing depositional sets; these relationships indicate the overall organization of space-use within a site. He is also interested in the detailed relationship among pairs of types within depositional sets and shared by sets; these can indicate, for example, tool kit and technological organization. However, MDS typically provides more accurate representation of the general, global structure of a data set at the expense of details of local structure (Graef & Spence, 1976).

To obtain accurate information on the internal organization of depositional sets and their patterns of overlap, several procedures can be used. (a) A separate MDS can be made for the artifact types composing each group of each set of interrelated groups that is defined in the global configuration of all types within the data set. (b) In each such separate analysis, *jacknife* procedures, which involve the systematic elimination of alternative, single types from consideration, can be used to determine finer-scale dependencies (Mosteller & Tukey, 1977). (c) In each separate analysis, the matrix of residual distances also can be examined for this purpose (Kruskal & Wish, 1978, pp. 33, 45-48).

4) Compensating for unreliability in some similarity values. The values taken by a similarity coefficient for different pairs of artifact types can vary in their reliability, depending on the number of items of each type comprising the pairs. Coefficient values for type-pairs where one or both types are represented by only a few items have a greater likelihood of being biased as a result of either inadequate sampling of cultural formation processes or the effects of post-depositional disturbance processes.

Under these circumstances, it would be desirable to weight the contributions of various similarity values to the total configuration in accordance with their probable reliability, as a function of the number of observations on which they depend. However, this option is not available in standard scaling programs. As a less desirable alternative, a MDS analysis of only those frequent artifact types that have the most probably reliable similarity values can be performed first. This baseline analysis can then be followed by ones that introduce less probably reliable types into the solution, either sequentially or on a replacement basis. The reliability of the similarity values associated with such an introduced type, and of the configuration including it, can be approximately assessed by the degree to which the configuration of types remains essentially stable after the introduction of the questionable type, provided that the number of likely reliable types is much larger than the number of possibly biased ones.

5) Screening and analyzing data with ubiquitously distributed types. Artifact types that occur ubiquitously across a site in high densities should not be included initially in a MDS analysis; they can cause distortions in results. If the similarity coefficients used to summarize the degree of coarrangement of types are AVDISTGM, AVDISTLP1, or the similarity measures of Jaccard or Cole, the ubiquitous artifact types will be characterized as differing in their arrangement from all of the more spatially restricted types. This will lead to a *space-dilating* effect in the MDS solution. If the coefficients used are AVDISTGP or AVDISTLP2, the ubiquitous types will be characterized as very similar in their arrangement to all more spatially restricted types. This will produce a *space-contracting* effect. The scaling procedures of most MDS algorithms will compensate for the global average degree of dilation or contraction so as to produce a configuration of standard size and stimulus coordinates of similar range. However, any local variations in the degree of dilation or contraction from group to group of types will still be manifested in the final configuration. This distortion can involve either minor alterations in the distances among types and among groups of types within a configuration, causing no effect on the composition of defined groups, or more substantial shifts in the positions of types, leading to new group compositions. Additionally, the relationship between configuration stress and dimension over the various representations of the data can be altered, particularly at lower dimensions. All of these effects are noted in the analysis of the Pincevent data (see pp. 439-441).

To avoid these undesirable effects, two different strategies can be used. The one which is appropriate depends on the nature and probable causes of the ubiquitous distributions (Carr, 1984). (a) Suppose that a type has a ubiquitous, high density distribution which is fairly *uniform or random* in nature. The difference between the form of its distribution and that of other types in the data set which have clustered distributions (ubiquitous or restricted in space) indicates the different patterns of use, deposition, and possibly post-depositional disturbance of the type. The different form of its distribution, alone, suggests that it does not belong to depositional sets that might be definable among the types having clustered arrangements, and that it should be removed from analysis.

(b) If a type has a ubiquitous, high density distribution that exhibits local *clusters* of artifacts within it, this suggests that its distribution is a complex *palimpsest* (see p. 321) resulting from at least two different depositional or post-depositional processes: one leading to the ubiquity of artifacts, the other to their clustering. In this case, the artifact type's distribution should be dissected into its component distributions—one or more clustered distributions of restricted spatial extent and one or more ubiquitous distributions. This can be achieved using spatial filtering or Fourier procedures that are concordant with the formation processes thought responsible for the components. Similarity measures should then be calculated between all other types and those components that have spatially restricted, clustered distributions rather than the composite, ubiquitous distribution. These coefficients should be used in the MDS analysis. Carr (1982a, 1984, 1986) discusses the theory and methods for such dissection.

(c) A less complicated but also less precise alternative to the dissecting method for handling artifact types with ubiquitous, high-density, clustered distributions can be used. First, a multidimensional scaling of those artifact types that do not have ubiquitous distributions and that will not distort analysis should be performed in order to determine the stable relationships among these types. Then, the ubiquitous, high-density, clustered types can be brought into the analysis, one at a time, on a replacement basis, to determine their positions within groups of nonubiquitous types. The positioning of each ubiquitous type within the configuration will depend more on the relation of its *clustered* component(s) to the distributions of the other types than its ubiquitous component(s), the latter being more equally associated with all types. Of course, the ubiquitous component(s), will cause some distortion to the configuration.

Only one ubiquitous, high-density, clustered type should be brought into the analysis at a time. This is necessary to maintain the compositions of groups of nonubiquitous types as stable as possible so that they remain identifiable and so that the relationship of the ubiquitous type to the groups is clear. Moreover, there is no advantage to bringing several ubiquitous types into an analysis simultaneously. The resulting configuration will not suggest the proper degree of association of the clustered component(s) of the ubiquitous types to each other. The types will tend to associate strongly as a result of the common arrangement of their ubiquitous components, thus masking the degree of similarity in the arrangement of their clustered components. This tendency will increase as the *intensity* of patterning within the distributions of the ubiquitous, clustered types decreases, i.e., as the density differences between clusters and their ubiquitous background decreases. All of these phenomena were noted in the Pincevent data analysis.

A New Clustering Algorithm Allowing Cluster Overlap: OVERCLUS

Multidimensional scaling is useful for providing a representation of the multiple relationships between artifact types, which indicates groups of types that are more or less coarranged over a site. Used by itself, however, the method has drawbacks. 1) Visual representations of the data become more difficult to construct graphically in greater than two dimensions, ultimately requiring mental visualization (Kruskal & Wish, 1978), which is subject to distortion. This problem is typically met in archaeological data sets with larger numbers of artifact types, where overlap among even moderate numbers of multitype groups may define complex structures requiring three dimensions or more to be displayed with low stress. 2) The method presents simply a configuration of artifact types positioned relative to each other; it does not define groups of types having similar arrangements relative to some threshold level of similarity.

Additional analytic steps can be used to amend these problems. These involve calculating a matrix of Euclidean distances between the stimulus coordinates that have been produced for all types in a low-stress, low-dimensional scaling of the data, and then applying a new clustering algorithm introduced here—OVERCLUS—to the matrix. The OVERCLUS algorithm results in a list of types that are similarly arranged, at a specified level of similarity, on a complete or partial linkage basis.

Other clustering routines listed in Table 7 might also be used for this purpose (Kruskal & Wish, 1978, pp. 44-46). However, they are less desirable for one or more of the reasons enumerated earlier: they do not allow the user to control the amount of inconsistency between pairwise type relationships that is smoothed out of the data; they do not allow groups of types to overlap; they require a priori specification of certain parameters; and/or they are inefficient. Additionally, some of the routines (ADCLUS, ITREG) do not allow the researcher to control the level of dissimilarity used in defining groups, making it impossible to investigate hierarchical, nested relationships among groups. This limitation is critical in archaeological applications, for tools and tool kits often exhibit hierarchically nested relationships within sites (see Carr, 1984 for a detailed discussion).

In outline, OVERCLUS works as follows. 1) The dissimilarity coefficients (n total) for all pairs of types are ordered in a sequence, from those indicating greatest similarity to those indicating least similarity. The ordered values, D_i ($i = 1 \rightarrow n$), become the levels of dissimilarity to be used as linking criteria in each of a series of fusion steps to follow.

2) Starting with the first, lowest level of dissimilarity D_l and proceeding to the final, greatest level of dissimilarity D_n, a series of fusion steps is initiated. At each step, all pairs of artifact types that have dissimilarity coefficients less than or equal to the given level of dissimilarity D_i are linked.

3) At each fusion step, a list of all linked pairs of types is generated. Under a complete linkage criterion, if three or more types are all mutually interlinked, then the *multitype* group is listed (e.g., *ABC*) in place of the multitype linkages among pairs (e.g., *AB*, *AC*, *BC*). A given type can be listed in more than one intra-linked group or linked pair, if it is so joined, which defines an overlapping set structure with the one type being shared among sets. Similarly, a linked pair or intra-linked group of several types can be listed in more than one more-encompassing intra-linked group, if the artifact types in the pair or group are so linked, which defines an overlapping set structure with more than one type shared among sets.

Linkage criteria less rigorous than the complete linkage one can be used. This can be achieved by allowing a multitype group to be listed when only a certain *percentage* of the pairwise relationships among the types comprising it (less than 100% and greater than 50%) are realized as linkages. By varying the percentage of realized linkages required for group definition, the researcher can control the degree of inconsistency between pairwise relationships among types that is ignored when constructing groups and defining a smoothed, summary configuration of the data at a given level of similarity. Using the complete linkage criterion (which requires 100% linkage of types within a group) results in a faithful, unsmoothed representation of the data, whereas using less stringent, partial linkage criteria produces smoother representations. Put in another, more standard perspective, the availability of both complete and partial linkage criteria allows the researcher to control whether groups are required to be hyperspherical in shape or permitted to be more amorphous, linear, or raggedy (Sneath & Sokal, 1973, pp. 216-245).

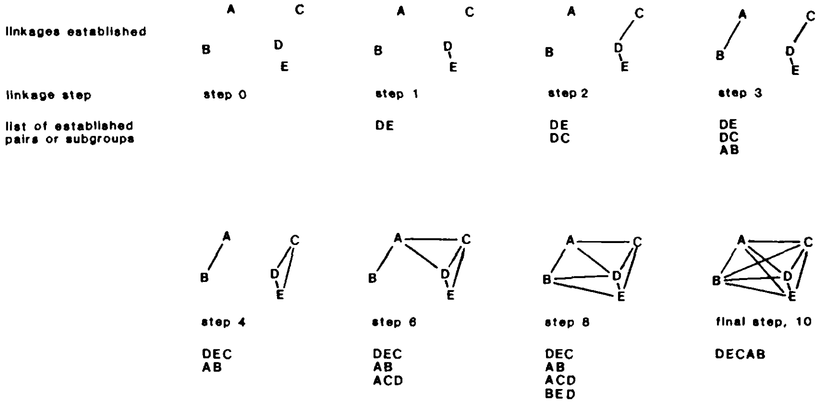
Caution must be used in specifying the degree of partial linkage required for group definition if a partial linkage approach is taken. Too liberal a criterion (low percentage requirement) can result in extensively overlapping groups and muddled results.

4) To determine the fusion step and degree of grouping most appropriate for displaying the data, two graphs are made: one of dissimilarity level vs. fusion step, and a second of the number of multitype groups or pairs listed vs. fusion

step. The graph of dissimilarity may rise slowly in some sections. This indicates that the artifact types being linked to others are joining them at relatively constant levels of similarity in arrangement, and that the groups being formed are relatively homogeneous internally in the degree of similar arrangement of their constituent types. In other places, the graph of dissimilarity may rise abruptly. This indicates that the artifact types being linked to others are increasingly more different in their spatial arrangements, and that the groups being formed are becoming less homogeneous in the degree of similar arrangement of their constituent types—an undesirable feature.

The graph of number of groups against fusion step will rise and fall repeatedly over its extent as different groups begin to form and then "crystallize" as the types within each group become more interlinked. Think of a multitype group that exists structurally within a data set (Fig. 8, step 0). As dissimilarity levels rise well below its threshold of definition, the number of discrete linked pairs and subgroups of types comprising the group-to-be at first increases. This occurs because not all of the pairwise linkages that are established among multiple types within the group-to-be are mutual ones (Fig. 8, step 2). Moreover, some types may link within one portion of the group, while separately, other types link within other portions of the group, forming various "seed" pairs and subgroups (Fig. 8, step 3). As dissimilarity levels continue to rise, however, linkages become more complete within multitype seed subgroups (Fig. 8, step 4); also, subgroups coalesce (Fig. 8, steps 6, 8). These "crystallization" processes lead ultimately to a reduction in the number of linked pairs and intralinked subgroups, until finally, the group-to-be emerges as one intrarelated structure (Fig. 8, step 10).

Fig. 13.8. As a potential group of artifact types becomes realized through the reduction of similarity thresholds and the creation of linkages between types, the number of linked pairs and subgroups at first increases and then decreases. Here, a complete linkage criterion is assumed.



Fusion steps that are optimal for displaying a data set and that have preferred groupings of types can be identified by using a set of prioritized, preferred characteristics of the data representations at the different fusion steps. These characteristics can be determined from the two kinds of graphs. First, the steps should be those where the number of listed linked pairs or intra-linked groups is at a local minimum compared to that at neighboring fusion steps. This indicates the crystallization of groups and a simplification of organization (Fig. 8, steps 4, 10). Second, of these steps, more optimal ones will be those that also have been preceded by fusion steps where dissimilarity levels rose only slightly. This indicates that the groups that have crystallized are also relatively homogeneous internally in the degree of similar arrangement of many of their constituent types. Finally, from this reduced set of fusion steps, the ones most preferred for displaying the data will be those defining groups of types that are interpretable, whether from the perspective of the preferred hypothesis on spatial arrangement, or alternative or unexpected ones.

For intrasite data sets having several groups of artifact types that do not overlap extensively—as suggested by their undissected MDS solutions—the use of multiple, different dissimilarity thresholds for defining different groups of types may be preferable to using any one global threshold for defining all groups. (The application of one threshold implies that all use-areas of different kinds have similar artifact densities, and secondarily, are of similar size, which need not be true.) The distance thresholds used to define groups of artifact types in different portions of a MDS solution should be consistent with (i.e., less than) the expected artifact densities and scales of *potential* use-areas of different kinds which are suggested by the relationships among artifact types in the undissected MDS solution. Among the factors that should be considered when defining the expected nature of use-areas and appropriate maximum distance thresholds are: the kinds of activities suggested by the potential groupings of artifact types, the space requirements of those activities, whether sweeping and cleaning of activity areas probably occurred, whether depositional sets have been smeared by contemporary farming (in the case of surface collections), etc. When using this alternative approach to defining groups of types, the two kinds of diagnostic graphs described previously may be less helpful in determining pertinent dissimilarity thresholds than a systematic examination of: (a) the *sequence of linkages* created as dissimilarity rises and (b) the particular dissimilarity levels at which various *potential* groupings crystallize.

OVERCLUS can be applied to an *unsmoothed* original matrix of dissimilarity or similarity coefficients of any of the kinds discussed in this chapter, or to a *smoothed* matrix of Euclidean distances between stimulus coordinates produced by MDS procedures, in order to obtain groups of types. In the former approach, the percentage of realized pairwise linkages that is required for group definition must usually be kept at less than complete. This is necessary to allow some inconsistencies between multiple pairwise relationships to be smoothed out of the data, so that the predominant patterning among types can be represented more clearly. In the latter approach, where MDS procedures have already smoothed out many inconsistencies, more complete or absolutely complete linkage requirements can be used.

At the present time, it is unclear whether multidimensional scaling procedures or direct application of OVERCLUS is preferable for smoothing intrasite spatial data or other kinds of data.

ILLUSTRATION OF THE PROPOSED ANALYTIC FRAMEWORK AND NEW TECHNIQUES

In this section, the French Magdalenian site, Pincevent habitation no. 1 (Leroi-Gourhan & Brézillon, 1966) will be analyzed. This will be done to 1) exemplify the proposed inductive and deductive analytic framework for recognizing spatial patterning of artifacts within sites, involving the use of entry models, 2) illustrate some aspects of depositional set organization encompassed by the several models of intrasite artifact organization that have been presented, and 3) illustrate the use of the AVDIST coefficients, OVERCLUS, and MDS procedures that have been introduced.

It must be stressed that not all of the studies to be presented would normally be undertaken as part of a routine spatial analysis for the purpose of behavioral reconstruction; some are included simply for heuristic purposes. Also, many additional analyses, such as those concerned with decomposing artifact palimpsests and with delimiting artifact clusters/depositional areas, would normally be a part of a spatial analysis, but are not included here, given the topic of this chapter.

Pincevent was chosen as the site to be analyzed for several heuristic reasons. 1) Artifact distributional data are in the form of item point locations, which makes possible the illustration of the AVDIST statistics. 2) The list of tool and debris classes for which distributional data are available seemed on initial inspection to include groups of *multiple classes* which might be expected, on the bases of previous functional analyses of Paleolithic tools, to define *single* depositional sets or archaeological tool kits (e.g., burins, burin spalls, and becs used in working bone, antler, and/or wood). This characteristic of the data was required in order to illustrate variation in the *internal* forms of organization of depositional sets (along the monothetic-polythetic dimension) in addition to their external forms of organization (along the nonoverlapping-overlapping dimension), and the sensitivity of different algorithms to these forms. In this regard, the data stand in contrast to those from the Mask site analyzed by Whallon (1984), which document primarily the external organization of depositional sets. 3) The distributions of most artifact classes were not of a ubiquitous, clustered nature or of other forms suggesting a complex palimpsest, which would require decomposition with Fourier and spatial filtering methods. Thus, the analysis for defining depositional sets did not have to be preceded by complex screening operations that would have made the illustration less obvious, and to some, less believable. 4) The site represents the remains of a relatively short-term occupation (see below); it thus meets the assumption of approximate contemporaneity of depositional episodes, which is necessary in most intrasite spatial analysis.

Overview of Pincevent

Pincevent (Leroi-Gourhan & Brézillon, 1964, 1966, 1972) is located in the Paris basin of northern France, on the floodplain of the Seine river, between the confluences of the Yonne and Loigne rivers with the Seine. It includes a number of small occupations at various stratigraphic levels. One of these, habitation no. 1 (Leroi-Gourhan & Brézillon, 1966), is a reindeer hunting camp dating to the late Magdalenian. A 12,300 B.C. ± 400 uncorrected carbon date is preferred for the occupation over several dates in the 9,300-10,000 B.C. range on the basis of the context of the carbon samples and laboratory reports on processing difficulties (E. Gilot, 1966). The site is one of a series of known Magdalenian occupations within the Paris basin, which occur primarily within the main river valleys and less so in upland settings.

The time of occupation of habitation no. 1 corresponds to the Bölling or Alleröd period at the end of the second cold maximum of the Würm glacial. This was a period of rapid glacial retreat with some very cold oscillations (Butzer, 1971, p. 274; Flint, 1971, p. 626). Winters, rather than summers, are thought to have been colder than those currently, and the climate may also have been more arid as a result of the colder temperatures (Butzer, 1971, pp. 280-286). Vegetation in central and northern France at this time is reconstructed to have been still of a tundra-like form, on the plains, including pioneer and drought-resistant species such as Artemesia (like sage brush) and chenopods; and of a parkland composition in the foothills of the Massive Central, where juniper, spruce, alder, and/or birches were scattered among the former (Flint, 1971, p. 632; Butzer, 1971, pp. 287-289). The tundra vegetation may have been of a composition atypical of current tundras, and possibly resembled more a grassy steppe including herbs (Butzer, 1971, pp. 287-289; Hahn, 1977, p. 204).

Habitation no. 1 is comprised by a scatter of lithic artifacts and bone debris around three hearths that are aligned in the SW-NE orientation (Fig. 9). Several aspects of the remains suggest that each hearth occurred within a hut, which was possibly made of poles and skins, and that the three huts overlapped so as to form a larger building with a common central gallery and multiple entrances. 1) Within the distribution of flint and bone debris occur concentrations in the form of arcs. These are presumed to represent where rubbish, which were generated by activities in the more central parts of the structure, were swept to its *sides* (Leroi-Gourhan & Brézillon, 1966, pp. 332-336, 361). 2) Along one arc, there are several hummocks of soil with larger flint nodules on top. These occur

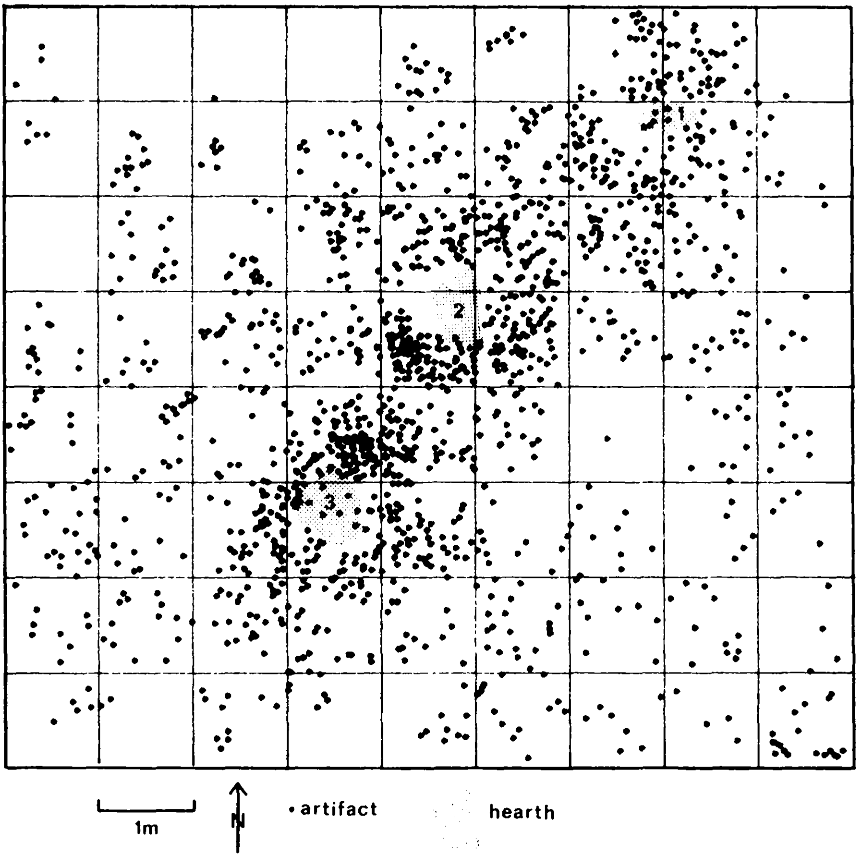


Fig. 13.9. Pincevent habitation no. 1.

on the prevailing upwind side of the structure and possibly represent positions at which tent poles were anchored (p. 362). 3) The concentrations of debris that define the hypothesized edges of the huts are not always delimited by a *sharp* boundary on their exteriors. This suggests that the huts were possibly of a tent structure in which swept debris was scattered under and somewhat beyond its skirt in places (p. 362). Tents of skin are a common form of housing among many mobile hunters of the arctic and subarctic, including the inland Eskimo and northern Athapascans of Canada (Speiss, 1979, p. 221). 4) Within much of the hypothesized building, and not anywhere outside it, a thin sprinkling of red ochre underlaid the artifacts, helping to define the building's outline (Leroi-Gourhan & Brézillon, 1966, pp. 330-332). The rationale for spreading ochre over the floor of the hut prior to its use is unclear. It was apparently swept, along with refuse generated within the huts, from several peripheral areas that were kept clean presumably for sleeping (pp. 331, 370).

The three huts and hearths seem to have been used contemporaneously rather than sequentially over the course of three separate occupations. This conclusion is based on several forms of evidence. 1) Most important, refitting studies of burins and burin spalls, cores and blades, and snapped blades indicate a rich network of joins among the three hearths and their surroundings (pp. 341-345, 349-350, 364). This might be seen, alternatively, as the product of recycling and mining behavior (Ascher, 1968; Reid, 1973) as the various huts were abandoned and occupied sequentially. However, some of the joins link items around a hearth of one hut to items against only the *walls* of *another* hut, suggesting activity around one hearth followed by the sweeping of debris from that activity against the walls of another hut which must have been standing at that time. 2) Some of the artifacts within habitation no. 1 are made of a red-brown flint, which is exotic to the Seine valley and which the occupants apparently brought with them to the site at its initial occupation. The latter is evidenced by the fact that all items of this flint are finished tools; no associated production debris or cores of red-brown flint for manufacturing these tools have been found at the site (Leroi-Gourhan & Brézillon, 1966, pp. 336-338). Importantly, the tools occur in *each* of the three huts and tool-refitting joins link pieces in the different huts. This suggests that the huts were contemporaneous components of a single structure used together during the initial occupation of the site, if mining was minimal. 3) The alignment and equi-spacing of the hearths suggests an integrated, organized use of the whole area rather than sequential, semi-randomly overlapping occupations. 4) Each of the three hearths is characterized by a similar stratigraphy. In each, the carbonaceous deposits are separated into two episodes of deposition by a thin, interbedded layer of sediment that possibly indicates a (brief?) period of site abandonment and water washing. This would suggest the contemporaneous use of all three hearths during both of two occupations, rather than their sequential use over two or three occupations. (For further evidence of two occupations, see below).

Binford (1983, pp. 158-159) has presented an alternative interpretation of habitation no. 1 that does not involve three interconnected huts. Rather, hearths 2 and 3 are envisioned as exterior hearths that were made and used sequentially in response to a change in wind direction during the course of a single occupation. Hearth 1 is thought possibly to have occurred inside a tent. The basis for Binford's interpretation is a supposed fit of the spatial arrangement of stone tool manufacturing debris around hearths 2 and 3 to his generalized model of a "men's outside hearth," which was developed using Nunamiut Eskimo data (Binford, 1978, pp. 348-350; 1983, pp. 149-156).

Binford's interpretation does not seem to be congruent with the Pincevent data in a number of ways, and thus is not preferred here to Leroi-Gourhan's reconstruction, which involves the three-hut structure.

1) Binford's model of a men's outside hearth specifies the accumulation of debris around one side of a hearth in two concentric arcs: an inner *drop zone* and

an outer *toss zone.* By the nature of the formation processes responsible for them, both zones—but especially the outer toss zone—should manifest themselves as gradients of debris density change rather than as sharply delimited arcs. In contrast, the exteriors of the arcs of debris at Pincevent (all artifacts considered) are sharply delimited in several areas (e.g., arcs IVb, c; VIa, b, c). It appears that debris had been moved—perhaps swept—up against some now-decomposed structure, such as the inside of a hut wall.

2) Binford's model specifies that the outer toss zone of debris should be wide, with 50-60 cm encompassing most artifacts in the Nunamiut case (2σ = 48-58 cm, depending on the artifact class; Binford, 1978, p. 349). In contrast, some of the arcs of debris around the hearths at Pincevent (e.g., VIa, b) are much narrower, as if debris had been moved *directly up against* some structure, such as the inside of a hut wall.

3) In addition to these two discrepancies between the *nature* of the arcs of debris at Pincevent and those in Binford's model, there is a discrepancy in the *positioning* of the arcs. Binford (1983, p. 158) states that the arrangement of debris from stone tool manufacture at Pincevent (Leroi-Gourhan & Brézillon, 1966, Fig. 56) "fits exactly" to the concentric arcs model of a men's outside hearth. I cannot find this positional resemblance for this debris class or any other artifact class, nor does Binford provide a statistical test of fit of the data to the model that might demonstrate such a resemblance. The manufacturing debris that constitute what Binford would apparently identify as a drop zone around the hearths concentrates immediately around them, within 0-.75 m of their edges, whereas the drop zone of Binford's model ranges from .4 to 1.0 m away from a hearth. The spatial arrangements of particular stone tool and debris classes (e.g., burins, burin spalls, backed bladelets, becs, cores) also show this discordance with the model. Rings of faunal artifact classes (e.g., ribs) around the hearths at Pincevent, which might be identified as toss zones, occur much too closely to the hearths (.1-1.5 m) to represent toss zones as defined by Binford's model (2-3.2 m away from a hearth's edge). In fact, most faunal elements ringing the hearths at Pincevent fall within essentially the same radius from the hearths as do the stone tools and manufacturing debris.

4) Perhaps most important, Binford's interpretation does not account for or is discordant with a number of data that are explained by Leroi-Gourhan and Brézillon's reconstruction. These data include the existence and placement of hummocks of soil with stones on top; the stratigraphy of the hearths; the systematic placement of the hearths; the spatial distribution of red ochre and its coarrangement with arcs of debris; the differences in the frequencies of various artifact types northwest and southeast of the hearths (see p. 447); and the similar frequencies of certain artifact types among all three hearths (see p. 449).

Thus, Leroi-Gourhan's reconstruction of three-interconnected huts is favored over Binford's outdoor hearth interpretation. The acceptance of Leroi-Gourhan's hut reconstruction, however, does not necessarily require acceptance of his conclusions on the residential as opposed to logistical nature of the site (Binford, 1978, p. 357), although the former interpretation is preferred for reasons given below.

Other habitations, presumably similar to no. 1, occur within a 2-hectare area of Pincevent, on the order of tens of meters apart. It was unclear at the time of publication of the site report whether these locations were occupied simultaneously with habitation no. 1 and represent an aggregation of social units, or indicate repeated reoccupation of the site, or both (Leroi-Gourhan & Brézillon, 1966, p. 371).

The approximate seasons of occupation of habitation no. 1 can be reconstructed from the age of kill of reindeer brought back to the site, the remains of which comprise nearly all of the faunal assemblage for the site. Leroi-Gourhan and Brézillon suggest, from the evidence, a late spring through November occupation that was probably continuous (ibid, p. 361). On the other hand, Guillien and Perpère (1966), the faunal analysts, find only a short period in late spring and a somewhat longer period during winter represented by the kills, there being no summer kills.

Reconstruction of the precise periods of occupation from the data at hand is difficult. The sample of ageable bones is small (18 pieces from 7 infants to juveniles). Moreover, the method that was used to determine age of kill was the degree of eruption of mandibular teeth, which can yield more variable results for incomplete specimens than was realized at the time of writing (Speiss, 1979, pp. 70-71). Nevertheless, the reconstruction of a discontinuous occupation, in winter and late spring, is consistent with at least two other data. First, as mentioned above, the stratigraphy within all three hearths suggests two episodes of occupation and deposition, with a period of waterwashing of sediments and possible site abandonment between them. Second, nearly all the tools in the habitation are found *within* the huts rather than outside, implying that most work took place inside. This would be expected in a winter context and less likely in a summer occupation of the kind suggested by Leroi-Gourhan and Brézillon.

Population estimates for habitation no. 1 are consistent with the numbers of persons typically found among winter microbands of artiodactyl hunters in the interior arctic and subarctic: a nuclear family of 5-7 persons to a group of 20 persons (Speiss, 1979, p. 221). The total floor area within the three huts in the site is ca. 30 m^2, corresponding to 6.4 persons using Narroll's (1962) regression and 2.6-7.4 persons using the data of Cook and Heizer (1968). The total floor space is typical of that of willow-frame/skin tents used by inland Eskimo and northern Athapascan hunters (20-33 m^2), which are occupied by 1 to 3 nuclear families (Speiss, 1979, p. 221). Leroi-Gourhan and Brézillon (1966, p. 370) estimate the probable population of habitation no 1. at 6 to 9 adults on the basis of the number of persons (2-3) that could have rested within each of three clearly debris-free areas, which are presumed to be sleeping areas within the huts, and a maximum of 10-15 persons considering two other possible resting places. The total population of Pincevent at the time of occupation of habitation no. 1 may or may not have included several such microbands in aggregation (ibid, p. 371).

It is possible to use these population estimates and other information to obtain a more precise estimate of the actual length of occupation of the site. Nearly all the bone debris in habitation no. 1 are of reindeer, which suggests the mainstay of the occupants' subsistence during the site's use. (Exceptions include: 1 bone of horse and several pieces of mammoth ivory, probably curated.) The estimated minimum number of reindeer of infant to juvenile age and adult age are 7 and 5, respectively (Guillien & Perpère, 1966, p. 377). These data can be used, along with nutritional data from Speiss (1979, pp. 28-29), to approximate the minimum (very conservative) number of man-days of food represented at the site. Taking into consideration nutritional variation with the age distribution and possible seasons of kill of the reindeer at habitation no. 1, a range of 101 to 227 minimum number of man-days of food are represented by the kill. If six adults occupied the site, this food supply would imply a minimum stay of 17 to 38 days; if nine adults, then 11 to 25 days. Thus, the actual length of occupation of habitation no. 1 appears to have been relatively brief. This result supports the suggestion of discontinuous use of the site rather than an extended late spring through November occupation, even considering the conservative nature of the estimated duration of stay. It also suggests a good context for spatial analysis, in which depositional areas are less likely to have been confused by their repeated relocation and overlap, with the growth of refuse.

The function of habitation no. 1 as a residential settlement or a more special purpose site (e.g., hunting stand, kill site) cannot be reconstructed with certainty from the data currently available. The interpretation of the site as a temporary residential settlement, however, seems preferable for several reasons. 1) The conservative minimum length of occupation of the site that has been estimated is more in line with a temporary residential settlement. 2) The range of activities that are reconstructed as possibly having occurred at the site (see pp. 423-428) includes *maintenance* tasks, such as making bone grease and working hide, (tacking, graining or sewing stages). 3) The location of the site in a floodplain rather than on some topographic rise with a good vista is not consistent with the interpretation of the site as a hunting stand.

The annual migratory and subsistence pattern of the occupants of habitation no. 1 is unclear, even by way of analogy to better-known regions and times. Three different patterns of human mobility have been reconstructed for regions to the southwest and northeast of Pincevent. In the Dordogne region to the southwest, during the Aurignacian, it appears that reindeer herds were followed from their summer pastures on the coastal plains to their wintering grounds in the sheltered valleys of the foothills of the Massif Central (Speiss, 1979, p. 234). To the northeast and east, Sturdy (1975, p. 74) has reconstructed that in the Late Glacial, herds were followed from their summer pastures in the foothills and mountains of central and southern Germany to their wintering grounds in the Flachland (coastal plain)—a pattern just opposite that to the southwest. Finally, Hahn (1977) has argued against Sturdy's reconstruction of long-distance migrations. He has assembled data that suggest a more localized exploitive strategy within southern Germany. The strategy involves tethered residential moves between large open-air winter sites in the foothills of the Alps and small spring and summer exploitive camps in both the valleys of the Jura mountains and the Jura plain.

Adaptations in the two areas adjacent to Pincevent may also have differed in the variety of animals that were used. Speiss (1979, p. 186) suggests the use of a variety of larger game animals in the Dordogne region. Sturdy (1975, pp. 79-94) describes a more focal, reindeer-based economy involving herd manipulation for the Flachland-German region, whereas Hahn (1977) suggests the use of a diversity of large and small terrestrial game and riverine resources in southern Germany.

Data Base

Choice of variables and observations. From the Pincevent assemblage, 23 artifact classes potentially reflecting specifiable activities or other formation processes were selected for distributional study. The artifact classes, abbreviations used for them in further analysis, and the activities and formation processes that they could indicate are shown in Table 8. The point location coordinates of items in the classes were recorded primarily from distribution maps given in the Pincevent site report (Leroi-Gourhan & Brézillon, 1966). Recording was done using a computerized digitizer that yielded item locations with a space dilating error of up to 4 cm over the 8 x 9 m grid, the error varying with the artifact class.

Items of four classes—piercers, micropiercers, notches, and lignite beads—were not plotted on maps within the site report; only their 1 m grid cell proveniences were mentioned in the text. The locations of each of these items were taken to be the centers of the grid cells in which they occurred, which produced locational errors of up to 71 cm (half the diagonal of the cells) for them. In a similar manner, a few items of some mapped classes were illustrated or mentioned in the text along with their grid cell proveniences, but not plotted on the class distribution maps (2 becs, 1 backed blade, 4 endscrapers). These items also were taken to be located at the center of their grid cells.

Endscrapers were divided into two classes: those with an approximately 60° edge angle (scrapa) and those with a bevel approaching 90° (scrapbc). This dichotomy was made on the basis of two a priori considerations. 1) It was thought that the dichotomy might distinguish those scrapers still usable and left in work areas from those exhausted and occurring in refuse areas. 2) It also was thought that the dichotomy might separate endscrapers used to deflesh hides from those used in graining hides (Carr, 1982b).

Table 13.8

Assignment of Functions to Artifact Classes within Pincevent

Artifact Class[1]	*Possible or Probable (*) Functions/Activities Indicated*	*Supporting Evidence*
V1. core (core)	*manufacture blades and bladelets (see below).	
V2. burin (burin)	*graving or boring primarily bone, antler, ivory.	Keeley (1978, p. 80; personal communication). Wear produced on stone tools used to work ivory is practically indistinguishable from that of bone or antler (Keeley, personal communication)
	*graving or boring wood less often.	Keeley (1978, p. 81)
	*groove-and-splinter technique.	local concentration of bone splinters with becs and burins between hearths 2 and 3 (Leroi-Gourhan & Brézillon, 1966, p. 364); (Clark, 1967, p. 64)
V3. burin spall (burinsp)	*see burin.	see burin
V4. bec and oblique truncations (bec)	*primarily boring, secondarily graving bone, antler, ivory.	Keeley (1978, p. 80; personal communication)
	*used for boring larger holes in contrast to those capable of being bored by piercers.	
	*groove-and-splinter technique on bone	Leroi-Gourhan and Brézillon (1966, pp. 320, 364), (Clark, 1967, p. 64), Semenov (1964), Clark and Thompson (1954), Keeley (1978, p. 80)
	pierce hides	Keeley (1978, p. 80)
	*rarely used on wood	Keeley (personal communication, on basis of evidence from Verberie, a site very similar in time and nature to Pincevent)
	truncations may be simply snapped blades, not used, or used for any of the purposes of utilized blades (see below).	Keeley (1978, p. 82)

Table 13.8 (cont.)

V5. piercers (pierce)	*bore bone, wood, deeper than micropiercers	tips snapped (Leroi-Gourhan & Brézillon, 1966, p. 293), Keeley (personal communication)
V6. micropiercers (microp)	*bore bone, less so wood, shallower than piercers; possibly decorative boring	Keeley (1978, p. 80; personal communication)
	*pierce hides	no snapped tips (Leroi-Gourhan & Brézillon, 1966, p. 293)
V7. notch (notch)	scrape wood or bone shafts	
	artifact of trampling	Keeley (personal communication)
V8, 9. endscraper, types A, BC (see text) (scrapa, scrapbc)	*primarily to grain dry hides, secondarily to scrape bone, wood, or deflesh hides	Keeley (1978, pp. 78-79), Semenov (1964, pp. 87-89), Barnes (1932, p. 53), Crabtree and Davis (1968), Gould et al., 1971; Hayden and Kamminga (1973), Mason (1889, 1899), Wilmsen (1970)
V10. backed bladelet (backbl)	*projectile point armatures/barbs set in grooved bone shaft or mastic.	2 backed bladelets stuck with mastic on an ungrooved bone splinter in another section of Pincevent; impact damage common on bladelets at the similar site, Verberie; any wear on Verberie specimens is from meat (Keeley, personal communication). Lithic analysis of Moss (1983).
	the multiple functions of utilized (backed or unbacked) blades (see utilized blade).	Some specimens are long enough (up to 4.2 cm; Leroi-Gourhan & Brézillon, 1966, p. 302) to have been used in this manner. Traces of wear usually on one side only (p. 304), indicating scraping, shaving, or whittling functions rather than cutting/puncture (Sollberger, 1969). Some burins, notches, made on backed bladelets (Leroi-Gourhan & Brézillon, 1966, pp. 302, 312) possibly indicating opportunistic tool manufacture during bone/wood working.
V11. utilized blade (utblade)	see backed blade	see backed blade. 41% of the blades in this category have natural backs (Leroi-Gourhan & Brézillon, 1966, p. 307)
	unused, trampled specimens	Keeley (personal communication)

Table 13.8 (cont.)

V12. lignite bead (bead)	*personal adornment	
V13. ivory (ivory)	*personal adornment	two pieces in association with a shell with two pearls; fossil shells pierced for wearing are found in other habitation sites within Pincevent (Leroi-Gourhan & Brézillon, 1966, p. 361)
V14. antler (antler)	*raw material for many antler items; worked by groove-and-splinter technique (see below)	Clark (1967, p. 64)
V15. phalanges (phal)	*preparation of broth by stone boiling foot minus hoof	partially articulated phalanges without terminal digits or hooves clustered around hearths with broken metapods (Leroi-Gourhan & Brézillon, 1966, pp. 352-353, 368)
	not used for making bone grease	although useful for this (Speiss, 1979, pp. 24-25), the phalanges are not broken up into small pieces as required (Leroi-Gourhan & Brézillon, 1966, pp. 352-353)
	not used as fuel	little bone within hearths (Leroi-Gourhan & Brézillon, 1966, p. 368)
V16. metapods (meta)	*preparation of broth by stone boiling foot minus hoof	see phalanges. Also, metapods of reindeer contain much marrow (Speiss, 1979, pp. 24-25). Those at Pincevent are broken at their extreme distal ends to free it to the broth (Leroi-Gourhan & Brézillon, 1966, p. 358)
V17. humerus, femur, radio-cubital (hfr)	*extraction of marrow	broken by percussion (Leroi-Gourhan & Brézillon (1966, p. 354); rich in marrow (Speiss, 1979, pp. 24-25)
	*raw material for many bone items (see below)	
V18. tibio-peroneal (tibio)	*extraction of marrow	see hfr
	*raw material for many bone items (see below)	
V19. scapula (scap)	*raw material for many bone items (see below)	Leroi-Gourhan & Brézillon (1966, p. 360)

Table 13.8 (cont.)

V20. rib (rib)	eat meat	
	*not used for making bone grease	Although useful for this (Speiss, 1979, pp. 24-25), the ribs are not broken up into small pieces as required (Leroi-Gourhan & Brézillon, 1966, p. 356)
V21. vertebrae (vert)	*refuse from butchering	Speiss (1979, pp. 21-25)
V22. maxilla (maxill)	teeth used as beads for personal adornment	Clark (1967, p. 64). Teeth other than those of reindeer also were used. A fossil shark's tooth was found with 10 pierced pieces of shell in another habitation within Pincevent.
V23. mandible (mandib)	teeth used as beads for personal adornment	see maxilla
	*extraction of marrow	rich in marrow (Speiss, 1979, pp. 24-25). Ascending ramus broken off of many specimens (Guillen & Perpère, 1966, pp. 374-377; site map)
V24. pebbles of alluvial flint (flint)	*raw material for hammerstones, cores	Leroi-Gourhan & Brézillon (1966, p. 325)
V25. sandstone and limestone (ssls)	*stone boiling, retain heat within hut	Leroi-Gourhan & Brézillon (1966, pp. 329, 367)

Supplement: Some Objects Made of Antler, Bone, and Wood during the Magdalenian in Southwest France and/or the Hamburgian-Ahrensburgian Region

Antler and/or Bone	lance heads, sometimes carved with motifs	(Bordes, 1968, p. 162)
	harpoon prototypes carved with motifs	(Bordes, 1968, pp. 162, 164)
	spear-throwers with ends carved with naturalistic representations of horse, ibex, birds, fish	(Clark, 1967, pp. 63-64)
	dart shafts	(Keeley, personal communication)
	clubs	(Clark, 1967, p. 65)
	bone wrenches ("pierced battons")	(Bordes, 1968, p. 163)
	needles	(Bordes, 1968, p. 163)
Wood	dart and arrow shafts	(Clark, 1967, p. 65)

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[1] Standard abbreviations for the classes are in parentheses.

The chance of defining either of these distinctions by dichotomizing along edge angle was considered low to moderate from the outset. The total number of endscrapers is small (26); for such small populations of endscrapers, variation among individuals in tool manufacture and the timing of tool deposition often can mask functional and depositional distinctions of the kinds sought (Keeley, personal communication, 1983). Nevertheless, the dichotomization was made on the chance that it might prove significant, holding in mind the option of later lumping all scrapers into one class. In the end, it did prove useful (see pp. 426-427, 429).

Of the 26 endscrapers within the site, only 25 could be identified to edge angle class (Lerio-Gourhan & Brézillon, 1966, p. 283) and used in the analysis.

The Pincevent assemblage includes several kinds of long bones that were distinguished on the site report maps: humeri, femurs, radio-cubitals, and tibio-peroneals. All could have been exploited for their marrow (Speiss, 1979, pp. 24-25) or bone in similar ways, and might have been defined as one analytic class. Or they might have been defined as four separate analytic classes. However, for this analysis, the first three were included in one class (V17) while tibio-peroneals were segregated in a class by themselves (V18). The basis for this classification was a noticeable clustering of humeri, femurs, and radio-cubitals without tibio-peroneals in some locations (between hearths 2 and 3, northeast of hearth 2), and isolated groupings of tibio-peroneals in other locations (e.g., northwest of hearth 2, around hearth 3 in various locations). These patterns suggested differences in the mode of deposition and possibly use of the two classes of items.

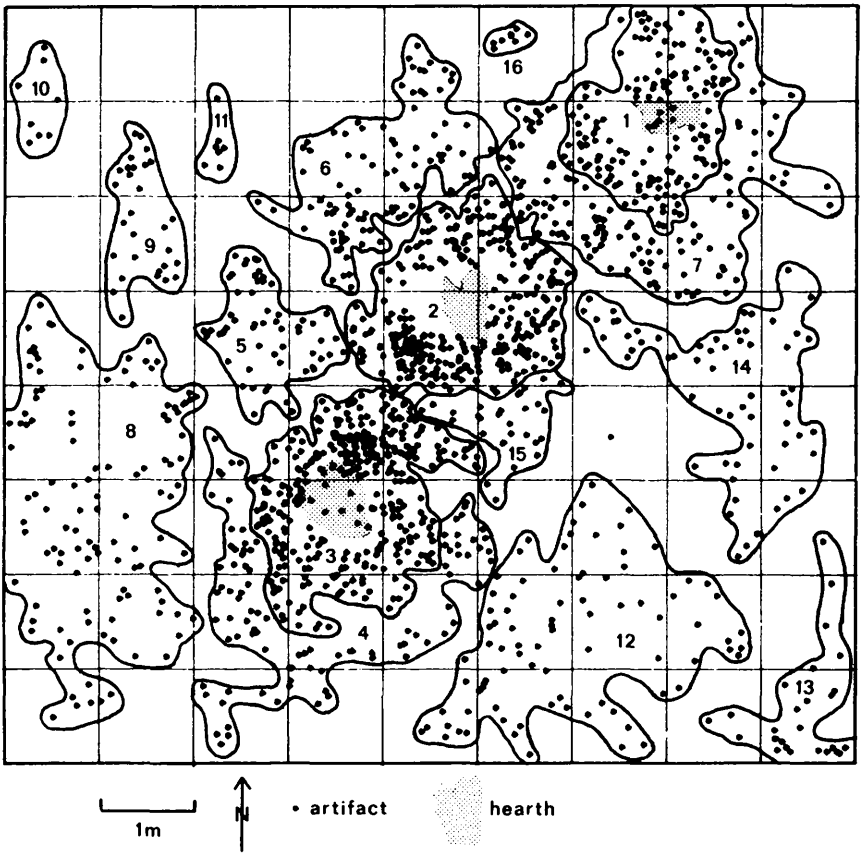
Mandibles and maxilla were retained as separate classes in light of the possible exploitation of only mandibles for their marrow (Speiss, 1979, pp. 24-25). There also were some visible distributional differences between them.

Choice of research universe. The entire excavated area of habitation no. 1 was selected for distributional study. Visual inspection of artifact distributions over the area did not reveal pooled contradictory structures (see p. 314) of the kind where different artifact type relationships of association/dissociation occur in different sectors of the site—a circumstance that would have mandated sub-global analysis of separate portions of the site. The areal variations in type relationships that were noticeable seemed to fall within the realm of polythetic organization variation.

Choice of analytic strata. To study patterning in the magnitudes and directions of asymmetry among artifact classes from locale to locale, and to employ the AVDISTLP1 similarity coefficient, it was necessary to stratify habitation no. 1 into natural areas within which depositional and disturbance processes were most likely homogeneous. The hut walls and zones within the huts that are defined by Leroi-Gourhan and Brézillon (1966, p. 324, Fig. 50) are seemingly attractive for delimiting such strata. However, they were found inappropriate for these purposes in at least two ways. 1) Although it is probable that three huts did comprise habitation no 1, arranged approximately as reconstructed, the precise locations of their walls are unclear in some places; several concentric arcs of flint and/or faunal debris mark some sides (Leroi-Gourhan & Brézillon, Fig. 56) and a few sides are indicated by only a gradation in debris density (ibid, p. 362) or not at all. 2) The authors stratified space within the huts only partially, using debris density contours. Similarly, not all areas outside the huts were stratified. Thus, although the stratification devised by Leroi-Gourhan and Brézillon was adequate for their purposes, it was too approximate and incomplete to serve as a basis for the quantitative analyses to be made.

As an alternative approach to stratification, natural clusters of artifacts were defined. This was done primarily on the basis of artifact density contours and clear circumscribing arcs of artifact concentration within the composite distribution of all classes of artifacts (Fig. 10). The density contours that were used

Fig. 13.10. Analytic strata 1–15 in Pincevent habitation no. 1, which were used to study patterns in the magnitude and direction of asymmetry of various artifact classes and in calculating AVDISTLP1 coefficient values.



to define clusters were allowed to vary locally in level, so as to not constrain all clusters to equal densities. Most of the clusters are spatially discrete and were easily defined. A few clusters grade into each other in small areas, but seemed to be easily resolved by arcs of concentration that continue from the unshared perimeters of the clusters into their gray zones (e.g., separation of strata 7, 2, and 14). The distributions of some individual artifact classes also helped to resolve some ambiguities. Some clusters (12, 6, 4) which occur predominantly within the interior of a hut extend slightly beyond the hut walls as approximated by Leroi-Gourhan and Brézillon. However, this seems permissible, given the approximate nature of the wall reconstruction and also the possibility that debris that was swept to the sides of the huts scattered under and somewhat beyond the tent skirts.

Identification of Formation Processes and Their Effects on Artifact Organization

Beyond artifact classification and the assignment of probable meanings to classes, the first responsibility of an archaeologist who is attempting an intrasite spatial analysis is to reconstruct, as best as possible, those formation and recovery processes that probably determined or affected the general nature of spatial organization of the artifact classes. Processes responsible for artifact organization along the monothetic-polythetic and nonoverlapping-overlapping dimensions, as well as those determining the palimpsest or simple nature of artifact class distributions, are of concern. On the basis of this knowledge, the archaeologist should then try to correct the data at hand for any systematic, natural post-depositional distortions within it and to decompose any complex artifact distributions into simpler ones that represent more homogeneous sets of formation processes. In other words, the archaeologist should develop a behaviorally relevant data structure. Finally, one should use the information on the formation processes that are responsible or probably responsible for the site to subsume the spatial data under one or a few entry models that specify the kinds of organizational relationships that occur or probably occur most frequently among artifact classes in the corrected, dissected data. The models, in turn, would suggest the one or few techniques that are most congruent with the data and appropriate for its analysis.

Excavations and lab research can be designed for collecting various kinds of observations that can be used to determine the formation processes responsible for an assemblage and its organizational nature (Schiffer, 1983). However, even when using published archaeological data that was not collected or reported with such a purpose in mind, it may be possible to gain considerable insight into an assemblage's development and actual or probable structure. The information analyzed for this purpose will vary from site to site with the documentation that is available and the behavioral and geological context of the site. The analysis of habitation no. 1 is a typical example of research carried out under these constraints.

The formation, recovery, and analytical and reporting processes that determined the nature of organization of artifact classes in habitation no. 1 along the monothetic-polythetic dimension and nonoverlapping-overlapping dimension are summarized in Tables 9 and 10. The pieces of evidence that were used to identify their occurrences, also given in the tables, are all observations of kinds not used by the quantitative methods that were applied to define depositional sets: they do not include the spatial proximities of items of different artifact classes to each other. This operational constraint has been followed to avoid the circular reasoning that otherwise would occur when justifying the application of a technique with information approximating the results of its application.

Table 13.9

Identification of Formation Processes at Pincevent: Factors Leading to "Unexpected Absences" of Artifact Types from Deposits

*Expected or Documented Process**	*Documentation*	*Organizational Model(s) along Monothetic-Polythetic Dimension (Fig. 3) likely Congruent with the Data*
1. Alternative tool types for same purpose	Large backed bladelets and utilized blades can be used for same tasks (Table 8), with possible exception of greater proficiency of backed blades in working harder materials. Also, many of the utilized blades (41%) have natural backs, making them functionally equivalent to the large, retouched backed bladelets.	Models 3, 4, 5, or 6
	Becs and burins are broadly functionally equivalent, used primarily to bore bone, antler (Keeley, 1978, p. 81), but may have slightly different uses.	
4. Differential discard rates	Burin; burin spall ratio of 130:206 (Leroi-Gourhan & Brézillon, 1966, p. 293; brown-	Models 2, 3, 4, 5, or 6

Table 13.9 (cont.)

	red artifacts brought to site partially used are not included).	
4. Non-expedient technology, curation	Several tool types (4 scrapers, 1 bec, 1 piercer, 5 burins, 18 utilized blades or truncations, 1 backed blade) of brown-red flint brought into site already manufactured (Leroi-Gourhan & Brézillon, 1966, p. 336). These same kinds of tools may have been removed from the site upon its abandonment. Conjoined burins and burin spalls (ibid, p. 344) and conjoined pieces of cores (ibid, p. 341), linking different work areas around different hearths, indicate locations where the same curated item was used at different times.	Models 3, 4, 5, or 6
5. Multipurpose tools	Utilized blades and large backed bladelets for working with meat, hide, vegetable, wood, or bone materials possible.	Models 3, 4, 5, or 6
6. Multitype edged tool	6-7 endscraper-burins not included in burin inventory (6-7 burins "unexpectedly absent," 120 present). One endscraper-piercer not included in piercer inventory (1 piercer "unexpectedly absent," 5 present). One burin-notch not included in notch inventory (1 notch "unexpectedly absent," 19 present).	Models 3, 4, 5, or 6
7. Recycling of artifacts	Burins were frequently made from artifacts of other types serving other functions. Of 78 burin spalls having platform remnants identifying them as	Models 3, 4, 5, or 6

Table 13.9 (cont.)

	such, 27 (35%) carried edges with retouch typical of endscrapers (ibid, p. 296)	
9. Size sorting of artifacts by sweeping	Sweeping likely since site is a winter/late spring occupation and most tasks performed inside tents, where open work space is limited. Sweeping indicated by debris-clear areas within the tents corresponding with areas lacking red ochre, which was sprinkled over the floor prior to use of the tents (ibid, pp. 330-332). Sweeping of areas possibly indicated by conjoining of pieces of cores (ibid, p. 341), broken utilized blades (ibid, p. 337, 349), and burins or burin spalls (ibid, p. 337, 344) along the walls of the huts with pieces within work areas around the hearths. Size sorting indicated by fact that of the conjoined burins and burin spalls separated between walls of the huts and work areas around the hearths, primarily burins (larger, sweepable) have been displaced to the walls while burin spalls (smaller, less sweepable) remain in the work areas. Possible size sorting of artifacts swept beneath skirt of tent (ibid, p. 362).	Models 3 or 5
10. Lack of preservation of some items of a class	Vertebrae easily decompose in acid soils like those of Pincevent. Of the ca. 500 vertebrae expected within habitation no. 1, based on the minimum number of reindeer	Models 3, 4, 5, or 6

Table 13.9 (cont.)

	brought there, only ca. 100 were recovered (ibid, p. 360).	
14. Technological rather than functional classification of artifacts	Large backed bladelets and utilized blades may have been functionally equivalent, and thus be artifically segregated (see above).	Models 3, 4, 5, or 6
	Scraper classes A and B may have been functionally equivalent, and thus be artifically segregated (see text: Data Base).	
	Tibio-peroneals, may have been used for same purposes as humeri, femurs, and radiocubitals, and thus artifically segregated (see text: Data Base).	
Incomplete inventorying of some items on distribution maps	206 burin spalls were excavated (Leroi-Gourhan & Brézillon, 1966, p. 293), only 68 of which (those conjoinable with burins) are indicated on the distribution map (33%).	Models 3, 4, 5, or 6
	66 backed bladelets were excavated (ibid, p. 312), only 60 of which are indicated on the distribution map (91%).	

*Same number given to process as in Table 4, where a full description of it is given.

Table 13.10

Identification of Formation Processes at Pincevent: Factors Leading to Overlap Among Depositional Sets

*Expected or Documented Processes**	*Documentation*	*Organizational Model(s) along Nonoverlapping-Overlapping Dimension likely Congruent with Data*
1. Multipurpose tools	Utilized blades and large backed bladelets for working	Overlapping

Table 13.10 (cont.)

	with meat, hide, vegetable, wood, or bone materials, possibly members or several kinds of tool kits.	
2. Multitype edged tools	2-3 endscraper-burins are included in both endscraper and burin inventories (2-3 out of 15 endscrapers = 13-20%; 2-3 out of 120 burins = 2-3%). 1 endscraper-piercer may be included in endscraper inventory (1 out of 15 endscrapers = 7%).	Overlapping
2. Agglomerated activity areas	A wide variety of activities (see Table 8) are represented by artifact types found in greater total numbers within the immediate hearth areas (Strata 1, 7; 2, 15; 3, 4) than peripheral areas (Strata 5, 6, 8, 9, 10, 11, 12, 13, 14, 16). These artifact classes include: core, burin, burin spall, bec, notch, backed bladelets, utilized blade, phalanges, metapods, ribs, (all > 2:1 ratio); hfr, mandibles (all > 1.5 and ≤ 2 ratio); endscrapers of classes A and B, ivory (all > 1 and ≤ 1.5 ratio).	Overlapping
3. Refuse from different kinds of activities deposited in same refuse areas through sweeping	See Table 9, entry 9, for evidence of sweeping. Conjoined burins and burin spalls (Leroi-Gourhan & Brézillon, 1966, pp. 337, 344) and conjoined pieces of cores (ibid, p. 341) indicate debris from different areas around a hearth or from different hearths were swept to common locations along the tent walls.	Overlapping
4. Post-depositional smearing of primary refuse by trampling	Trampling likely, given a winter/late spring occupation where most tasks done within	Overlapping

Table 13.10 (cont.)

	tents, and given frequent socializing and movement between hearths. The latter is indicated by the conjoining of burins and burin spalls, and pieces of cores around different hearths with each other (ibid, pp. 341, 344).	
5. Typological rather than functional classification	Some utilized blades have natural backs (41% of the items in the class) and possibly functioned like large retouched backed bladelets. The larger of the backed bladelets may have functioned like utilized blades, while the smaller specimens may have served as projectile point armatures. Many items in the class, becs, are simply obliquely truncated blades (19 of 45 items = 42%, ibid, p. 287), which may have been simply snapped blades used for any of the purposes of backed or utilized blades, but may also have been used like becs (ibid, pp. 287-288).	Overlapping

*Same number given to process as in Table 5, where a full description of it is given.

Many of the observations also are of simple kinds that are available in many other published site reports. These data include 1) the probable functions of various tool forms based on previous studies of Paleolithic tool function, experimental studies in lithics, ethnographic analogy, and site-specific information; 2) the season(s) of occupation of the site as reconstructed from faunal remains; 3) patterns of lithic tool recycling and reuse evident from tool morphology; 4) spatial patterns for various individual artifact classes; 5) bone classes that have anomalously low numbers of elements compared to those expected on the basis of the estimated minimum number of individuals, in turn indicating differential preservation patterns; 6) various aspects of the composite distribution of all artifact types (e.g., arcs of artifact concentrations indicating tent wall locations; the density of cluster boundaries; the occurrence of most artifacts within the tents); 7) the diversity of tool classes found in various locations; and 8) the nature of the artifact classification scheme used by the researchers.

Processes affecting organization along the monothetic-polythetic dimension. Of the identified processes that can cause "unexpected absences" of artifacts and that determine depositional set organization along the monothetic-polythetic dimension (Table 9), almost all very probably acted *disuniformly* over habitation no. 1 (Table 4). Their effect would thus have been to make any depositional sets that do exist at the site to be organized in the form of model(s) 3, 4, 5, or 6 (Fig. 4). The specific form would depend on the particular actions of the processes and the organizational nature of the activity sets from which the depositional sets were derived. If it is also considered that the different processes were *not correlated* over space with each other, then the result of their combined effects would have been to make depositional sets organized more probably in the form of models 4 or 6.

It is necessary to determine whether the *strengths* of the processes that can cause unexpected absences and the *magnitudes* of their effects on depositional set organization were significant. If they were not, then depositional sets might have internal organizations essentially congruent with a different array of models, including more restrictive ones. Also, some estimate of the *range* of artifact types and depositional sets that were affected by the processes must be made. If only a few types or sets were affected, then the data as a whole might be approximately congruent in structure with a different array of models, again including more restrictive ones.

The magnitude of the effects of many of the formation processes that determine set organization along the monothetic-polythetic dimension and that have been identified for habitation no. 1 can be roughly estimated. This can be done using the number of unexpected absences of items in a class that have resulted from the action of the processes, expressed as a percentage of all items that *should* be in the class, present and absent. Measures of the monotheticness and polytheticness of depositional sets discussed at the beginning of this chapter cannot be used because such sets are not yet defined.

Formation, disturbance, and recording processes at Pincevent clearly had considerable effects on a number of artifact classes and their monothetic or polythetic organization into sets. 1) Incomplete documentation of the positions of 138 burin spalls and 6 backed bladelets on the distribution maps of these artifact classes has resulted in 67% and 9% of the items of these classes (respectively) being absent from locations where they might otherwise be expected. 2) Absences of the multitype edged tools—endscraper-burins, endscraper-piercers, and burin-notches—from the distribution maps of burins, piercers, and notches are 5% (6-7 items), 17% (1 item), and 5% (1 item), respectively. 3) Of the 500 minimum number of vertebrae of reindeer expected to occur within the habitation, only about 100 were found, probably as a result of decomposition processes or their use as fuel, yielding 80% of the items of this class unexpectedly absent. 4) Of the 73 utilized blades at the site, 41% have natural backs and functionally should have been classified with retouched backed bladelets (60 total, mapped), yielding 33% unexpected absences of items within the backed bladelet class. 5) Of 120 burins, 20 occur at the reconstructed perimeter of the huts, apparently swept there from more central work areas. This implies unexpected absences of burins from the work areas on the order of at least 18%. Similarly, of 68 burin spalls, 9 occur peripherally, implying 13% unexpected absences of items of this class from central work areas. These percentages pertain to burins and burin spalls in relation to *other* artifact types with which they might be coarranged. The percentages would be less for burins and burin spalls in relation to each other, given the parallel decrease in their numbers from work areas. 6) If endscraper types A and BC (7 and 18 items, each) were functionally equivalent and should not have been separated into two classes, their separation would imply unexpected absences of endscrapers from a composite class on the order of 28% (7 out of 25 items) and 72% (18 out of 25 items). 7) Similarly, if utilized blades (73 items) and the larger of the backed bladelets (perhaps half of the 60 specimens, with lengths approximately greater than the mean bladelet size of 3.3 cm) were functionally identical, their separation would imply unexpected absences of blades and larger bladelets from a composite class on the order of 71% (73 out of 103 items) and 29% (30 out of 103 items). 8) If tibio-peroneals and radio-cubitals (93 items, total) should have been kept together as a single class, their separation would imply 36% and 74% unexpected absences of long bones from the composite class (32 out of 122 items, 93 out of 122 items, respectively). Thus, the classes of artifact types at habitation no. 1 that are known or suspected to have been affected by formation, disturbance, recovery, reporting, and analytic processes that determine monothetic or polythetic depositional set organization were affected *substantially*.

The range of artifact classes that were possibly or definitely affected by formation and other processes to a significant degree is great. At least 10 of the 11 artifact classes, for which information was available on the magnitude of effects of formation processes on them, exhibit unexpected absences at the 15% level or larger. It is likely that additional artifact classes were affected to a similarly significant degree by one or more of the processes given in Table 9, but the magnitudes of the effects could not be assessed. Sweeping, for instance, is thought to have been spatially extensive, based on spatial patterns of conjoined artifacts. It probably affected the distributions of many kinds of artifacts additional to those just discussed. The effects of trampling, unknown for any artifact classes, probably were great, given that work was done within the confines of the living quarters.

Thus, *considering the diversity of formation, recovery, reporting and analytic processes causing unexpected absences, the magnitudes and range of their effects, and their lack of* *spatial correlation, it can be concluded that either Models 4 or 6 best typify the organization of depositional sets within habitation no. 1 along the monothetic-polythetic dimension. Similarity coefficients congruent with these models must be used to analyze the data.*

Processes affecting organization along the nonoverlapping-overlapping dimension. Overlap among at least some depositional sets in habitation no. 1 is likely, given the formation processes that have been identified for the site and that lead to this kind of organization (Table 10). The extent of overlap among sets and number of sets exhibiting overlap cannot be estimated at this stage. *It is necessary, therefore, that the higher-level techniques that are chosen for grouping artifact classes into depositional sets allow but not require the sets to be overlapping.*

Palimpsest organization. Two artifact classes at Pincevent—pebbles of alluvial flint (V24) and sandstone and limestone (V25)—have relatively ubiquitous distributions that also exhibit local clustering. These distributions are probably palimpsests. In a full spatial analysis, each would have to be dissected into their component distributions (at least two—a clustered and a ubiquitous component) of more homogeneous origin. Only the clustered components would be analyzed with the other artifact classes in defining depositional sets; the ubiquitous components would be analyzed separately. However, because dissection of palimpsests requires spatial filtering or Fourier procedures (Carr, 1982a, 1986) that are beyond the scope of this chapter, the distributions of alluvial pebbles and sandstone/limestone will not be dissected. An alternative approach will be taken, whereby first an analysis is made of the nonubiquitously distributed types and then the few ubiquitously distributed types are added to the study (see pp. 379-380, 423).

Formal Linkage of the Pincevent Spatial Data Set to Techniques Appropriate for Its Analysis

To this point, many of the steps in the pattern-searching framework that is shown in Figure 2, which combines inductive and deductive elements, have been addressed or carried out informally. These steps can be reiterated and the analysis can proceed in more formal terms using the concepts of entry models and parallel data sets, in order to deduce the particular mathematical techniques probably most appropriate for analyzing the Pincevent spatial data set.

1) A variety of forms of archaeological evidence not to be used in the spatial analysis of habitation no. 1, as well as information on the site's behavioral and environmental contexts, have been assembled. These constitute a "parallel data set" (Carr, chapter 2).

2) The parallel data set has been used *inductively* to reconstruct the cultural and natural formation processes that operated at the site. Recovery processes and documentation processes also have been identified.

3) The spatial data have been modified in reference to some of these processes and in preparation for analysis to the extent that artifact types with complex palimpsest distributions have been screened from initial analysis. Greater

modification of the data in order to correct for the effects of natural formation processes would have been desirable, had information on their operation been available.

4) On the basis of the formation processes, other processes, and relationships among them that have been reconstructed for the habitation no. 1 spatial data, and also considering whether these processes and relationships are similar to those specified by the various entry models developed previously, it is possible to *subsume* the spatial data set under either of two entry models. Both entry models enumerate kinds of formation processes and relationships among them that are similar to those reconstructed for habitation no. 1. One, however, specifies internal depositional set organization of the Model 4 type whereas the other specifies internal depositional set organization of the Model 6 type. Both entry models allow overlap among depositional sets.

5) Given the subsumption of the habitation no. 1 data under the two entry models and the fact that these models list mathematical techniques having assumptions that are congruent with the archaeological organization specified by the models, it is possible to *deduce* those techniques probably most appropriate for searching the data for depositional sets. These algorithms include the similarity coefficients, AVDISTLP1 and AVDISTLP2, coupled with some higher-level pattern-searching technique(s) allowing sets to overlap, such as MDS and/or OVERCLUS.

Depositional Sets at Habitation No. 1.

Method of Definition of Sets

For purposes of illustration, only AVDISTLP1, of the two coefficients thought congruent with the Pincevent data set, will be used to analyze it.

Measuring similarity and multidimensional scaling. Using the computer program POLYTHETIC2 (Appendix A), a 23 x 23 matrix of AVDISTLP1 dissimilarity coefficients among all the nonubiquitous artifact types was calculated (Table 11). From this matrix, scaled configurations of the types in spaces ranging from 6 dimensions to 1 were derived using nonmetric MDS procedures provided within the Statistical Analysis System (Proc ALSCAL, Level = Ordinal, Converge = .0001). Either nonmetric or metric MDS procedures might have been applied, given the ratio scale of the item-distance data; however, the former were preferred, for their greater usefulness in determining the optimal number of dimensions for displaying data (see pp. 376-377). Degeneracy of the nonmetric solution was not expected given the probable overlap among depositional sets, nor did it occur. Plots of configuration stress (Kruskal's formula 1; Kruskal & Wish, 1978, p. 24) against dimensionality, and an R^2 statistic (Young & Lewyckyj, 1980) against dimensionality, indicated an optimal compromise between low dimensionality and accurate representation of the data's dominant structure at 2-3 dimensions (Fig. 11, Table 12). The R^2 statistic, which indicates

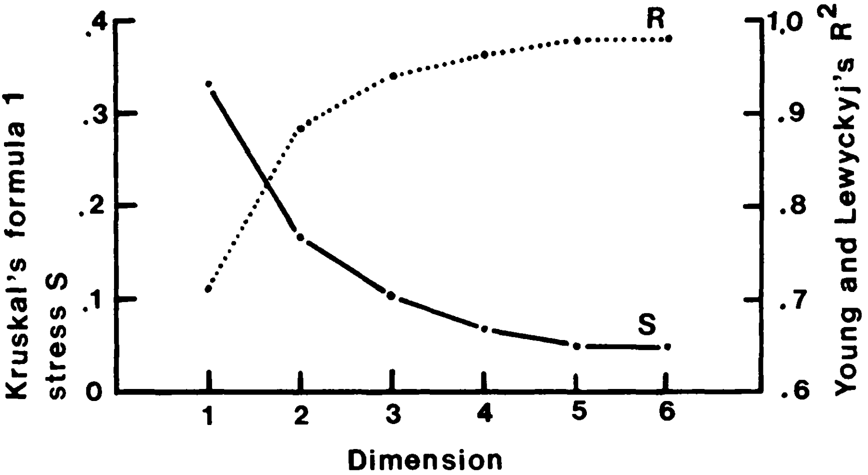


Fig. 13.11. Plots of configuration stress against dimensionality and of an R^2 statistic against dimensionality for a multidimensional scaling of 23 artifact classes from Pincevent. The AVDISTLP1 similarity coefficient was used. A 3 or 2 dimensional solution seems optimal.

the percentage of variation in the distances among types in full dimensional space that is encompassed by the distances among types in reduced space, is 94.2% for the 3-dimensional solution and 88.4% for the 2-dimensional solution. A plot of the distances among types in reduced space (disparities) against their distances in full dimensional space indicated that it was unlikely that classical scaling methods would facilitate much improvement in the representation of the data in 2- to 3-dimensional, reduced space. Several trial classical scalings also suggested this. The monotonic scalings were therefore accepted for further analysis. The configuration of types in 3-dimensional space, shown in Figure 12, was chosen for analysis.

Finer-scale multidimensional scaling. An examination of the 3-dimensional configuration indicated the possibility that the relationships within and between some clusters were distorted. Central to the configuration is a group of 11 artifact types (hereafter called *central types*), which probably is divisible into two or more subgroups. Central types include core, burin, burinsp, bec, notch, backbl, utblade, phal, meta, hfr, and rib. Surrounding this central cluster are 12 types (hereafter called *peripheral types*), some of which occur at great distances from the central group and comprise single or multitype "clusters." Because MDS usually reflects the global relationships among dispersed clusters more accurately and at the expense of local structural detail (Graef & Spence, 1976), it was concluded that the relationships among the 11 central artifact types and the composition of their subgroups might be distorted. Distortion of the rela-

Table 13.11

Matrix of AVDISTLP1 Statistics Defined for Habitation No. 1

	Core	*Burin*	*Burinsp*	*Bec*	*Notch*	*Backbl*	*Utblade*	*Phal*	*Meta*	*Hfr*	*Pierce*
Core	0.000	0.577	0.622	0.586	1.034	0.519	0.629	0.592	0.761	0.785	1.799
Burin	0.577	0.000	0.361	0.341	0.685	0.453	0.281	0.267	0.586	0.372	1.600
Burinsp	0.622	0.361	0.000	0.287	0.401	0.327	0.382	0.469	0.756	0.909	2.015
Bec	0.586	0.341	0.287	0.000	0.421	0.376	0.405	0.562	0.731	0.892	2.035
Notch	1.034	0.685	0.401	0.421	0.000	0.436	0.497	1.156	1.453	1.538	1.569
Backbl	0.519	0.453	0.327	0.376	0.436	0.000	0.380	0.552	0.823	0.998	0.804
Utblade	0.629	0.281	0.382	0.405	0.497	0.380	0.000	0.375	0.629	0.440	2.337
Phal	0.592	0.267	0.469	0.562	1.156	0.552	0.375	0.000	0.404	0.264	2.940
Meta	0.761	0.586	0.756	0.731	1.453	0.823	0.629	0.404	0.000	0.376	2.561
Hfr	0.785	0.372	0.909	0.892	1.538	0.998	0.440	0.264	0.376	0.000	2.326
Pierce	1.799	1.600	2.015	2.035	1.569	0.804	2.337	2.940	2.561	2.326	0.000
Microp	1.485	0.776	0.733	0.601	0.743	0.691	0.435	1.415	1.597	1.654	1.745
Scrapa	1.792	1.899	1.686	1.496	1.410	1.211	1.449	1.977	2.325	2.119	2.094
Scrapbc	0.793	0.990	0.999	0.647	0.563	0.465	0.725	1.037	1.179	1.118	1.609
Bead	2.553	2.234	2.012	2.020	2.116	2.109	2.537	3.087	3.512	3.002	1.047
Ivory	1.882	2.001	1.446	1.829	1.416	1.655	2.345	2.301	2.734	2.730	1.994
Antler	1.302	1.271	1.379	1.525	1.631	1.657	1.486	1.570	1.490	1.406	1.395
Tibio	0.445	0.622	1.108	0.998	1.208	0.912	0.647	0.570	0.535	0.532	2.221
Scap	1.418	1.585	1.885	1.783	1.851	1.838	1.619	1.432	1.542	1.651	2.019
Rib	0.661	0.443	0.717	0.601	1.104	0.738	0.375	0.379	0.400	0.319	2.694
Vert	1.883	1.828	1.607	1.744	1.856	1.671	2.325	2.393	2.904	2.674	1.757
Mandib	1.342	1.055	0.880	0.986	1.340	1.170	1.256	0.886	1.154	1.174	1.813
Maxill	0.953	0.776	0.876	0.782	1.079	0.979	0.945	1.034	1.031	1.291	1.479

	Microp	*Scrapa*	*Scrapbc*	*Bead*	*Ivory*	*Antler*	*Tibio*	*Scap*	*Rib*	*Vert*	*Mandib*	*Maxill*
Core	1.485	1.792	0.793	2.553	1.882	1.302	0.445	1.418	0.661	1.883	1.342	0.958
Burin	0.745	1.899	0.990	2.234	2.001	1.271	0.622	1.585	0.443	1.823	1.005	0.776
Burinsp	0.733	1.686	0.999	2.012	1.446	1.379	1.108	1.885	0.717	1.607	0.880	0.876
Bec	0.601	1.496	0.647	2.020	1.829	1.525	0.998	1.783	0.601	1.744	0.986	0.782
Notch	0.719	1.410	0.563	2.116	1.416	1.631	1.208	1.851	1.104	1.856	1.340	1.079
Backbl	0.691	1.211	0.465	2.109	1.655	1.657	0.912	1.838	0.738	1.671	1.170	0.979
Utblade	0.423	1.449	0.725	2.537	2.345	1.486	0.647	1.619	0.375	2.325	1.256	0.945
Phal	1.415	1.977	1.037	3.087	2.301	1.570	0.570	1.432	0.379	2.393	0.886	1.034
Meta	1.597	2.325	1.179	3.512	2.734	1.490	0.535	1.542	0.400	2.904	1.154	1.031
Hfr	1.615	2.119	1.118	3.002	2.730	1.406	0.532	1.651	0.319	2.674	1.174	1.291
Pierce	1.745	2.094	1.609	1.047	1.994	1.395	2.221	2.019	2.694	1.757	1.813	1.479
Microp	0.000	1.216	0.715	2.610	1.915	1.958	1.444	2.012	1.269	2.673	1.560	1.565
Scrapa	1.145	0.000	1.466	2.981	1.989	2.644	1.918	1.914	1.439	3.255	1.750	1.924
Scrapbc	0.715	1.466	0.000	2.621	2.439	1.829	0.893	1.626	1.040	2.641	1.790	1.589
Bead	2.610	2.981	2.621	0.000	1.735	1.849	2.876	2.983	3.365	1.171	2.722	2.056
Ivory	1.915	1.989	2.439	1.735	0.000	2.375	2.779	3.044	2.717	1.694	2.060	1.840
Antler	1.958	2.644	1.829	1.849	2.375	0.000	1.263	0.874	1.549	1.855	1.396	1.147
Tibio	1.444	1.918	0.893	2.876	2.779	1.263	0.000	1.432	0.509	2.738	1.698	1.318
Scap	2.012	1.914	1.626	2.983	3.044	0.874	1.432	0.000	1.691	3.341	1.610	1.572
Rib	1.269	1.439	1.040	3.365	2.717	1.549	0.509	1.691	0.000	2.987	1.513	1.466
Vert	2.673	3.255	2.641	1.171	1.694	1.855	2.738	3.341	2.987	0.000	2.143	1.709
Mandib	1.560	1.750	1.790	2.722	2.060	1.396	1.698	1.610	1.513	2.143	0.000	1.143
Maxill	1.565	1.924	1.589	2.056	1.840	1.147	1.318	1.572	1.466	1.709	1.143	0.000

Table 13.12

Stress of and Percent Variance of Data Explained by Configurations in Spaces of Different Dimensions

Number of Dimensions	*Global Monothetic Algorithm (AVDISTGM)*		*Local Polythetic Algorithm (AVDISTLP1)*		*Global Polythetic Algorithm (AVDISTGP)*	
	stress*	$\%\sigma^2$	stress*	$\%\sigma^2$	stress*	$\%\sigma^2$
10 Type Study						
6	no solution possible		no solution possible		no solution possible	
5	no solution possible		no solution possible		no solution possible	
4	.009	99.9	.013	99.9	.052	96.0
3	.028	*99.5***	*.051*	98.1	*.094*	*89.7*
2	*.091*	*96.2*	*.123*	*93.3*	*.176*	*78.4*
1	.370	53.9	.260	79.8	.370	53.9
23 Type Study						
6	.041	98.9	.047	98.2	.088	91.6
5	.051	98.4	.055	97.8	.110	89.1
4	.067	97.5	.076	96.5	.134	85.9
3	.098	95.3	*.105*	*94.2*	.181	81.2
2	*.157*	*90.2*	*.170*	*88.4*	*.230*	*76.3*
1	.382	61.1	.333	71.5	.382	61.1
10 Type Study With 2 Ubiquitous Types						
6	no solution possible		no solution possible		no solution possible	
5	.010	99.9	.017	99.7	.036	97.2
4	.034	99.2	.045	98.3	.068	*92.9*
3	.046	98.7	*.060*	*97.5*	*.125*	*83.5*
2	*.089*	*96.2*	*.120*	*93.3*	.232	66.3
1	.426	44.9	.207	86.0	.426	44.9

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*Kruskal's Stress formula 1. (Kruskal & Wish, 1978).

**Italics indicate that dimension for which an elbow in the graphs of stress vs. dimension or percent variance explained vs. dimension is observed.

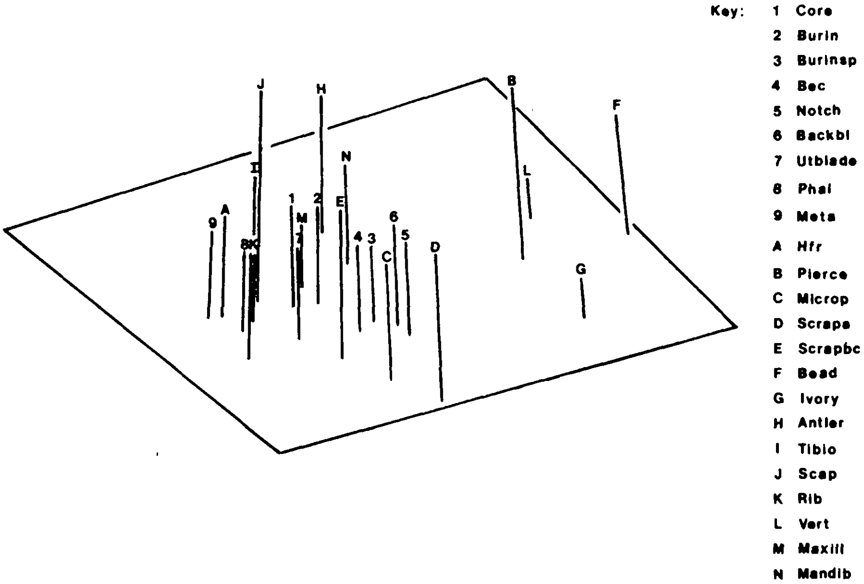

Fig. 13.12. A three-dimensional configuration of 23 artifact classes from Pincevent produced by their multidimensional scaling with the AVDISTLP1 similarity coefficient. The configuration is shown in perspective, using the same scaling factor for each dimension.

tionships among the central types also seemed likely, given that many of the peripheral types are infrequent (Table 22; 9 of the 12 types have less than 12 items) and the estimates of their relationships to the central types have a greater probability of being biased. To the extent that the relationships of the infrequent peripheral types to the central types are biased in complementary ways, the relationships of the central types to each other will be distorted more extensively. Thus, a more local MDS analysis, concentrating on the central group of 11 types, seemed appropriate before grouping types formally into depositional sets.

The choice of which particular types to include in the more local analysis was made entirely on the basis of the structure of the 3-dimensional configuration. The choice also, however, is meaningful: the 11 central artifact types are those that concentrate predominantly around the hearths of the site rather than in more peripheral strata (Table 13). Thus, the more local analysis can be viewed as a more detailed view of predominantly hearth-oriented depositional patterns.

A local MDS of 10 of the 11 central types was performed. (Rib unfortunately was deleted from analysis for reasons no longer felt justifiable but without ultimate consequences.) Those AVDISTLP1 coefficients within the larger matrix (Table 11) that are pertinent to the relationships among the 10 central

Table 13.13

Proportions of Artifacts of Given Types within Hearth Strata vs. Peripheral Strata*

	More Hearth-Oriented Types			*Less Hearth-Oriented Types*
#s within hearth strata / #s within peripheral strata :	*>2*	*2–1.51*	*1.5–1.01*	*≤1*
	core	hfr	scrapa	pierce
	burin	mandib	scrapbc	microp
	burinsp		ivory	bead
	bec			antler
	notch			tibio
	backbl			scapula
	utblade			vert
	phal			maxill
	meta			
	rib			

*Hearth strata include H1, H2, and H3. Peripheral strata include 8, 9, 10, 11, 5, 6, 16, 12, 13 and 14.

types were used to define monotonically scaled configurations of the types in spaces of 6 dimensions through 1, as before. Based on the stress and R^2 values for these solutions (Table 12), a 2 or 3-dimensional representation of the data seemed optimal. To maintain consistency with the previous analysis and also to gain "accuracy" in representation, the 3-dimensional solution, which encompasses 98.1% of the variation in the distances among the types in full dimensional space, was selected for further examination. The configuration (Fig. 13) exhibits a series of overlapping "clusters" or clinal relationships among types, without distant outliers. This feature, as well as the larger number of items upon which *all* AVDISTLP1 coefficients are based, suggests that the representation of the relationships among the types is probably more accurate than that for the 23 type solution. The larger R^2 statistic for the 10 type solution is consistent with this view.

Definition of depositional sets was achieved by a two-stage clustering design.

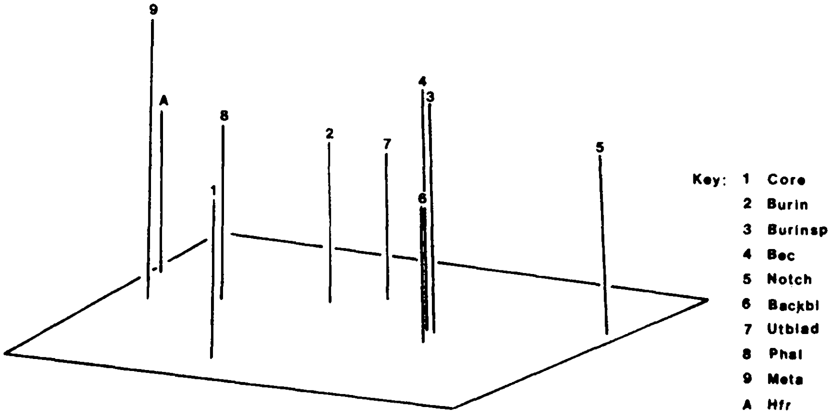

Fig. 13.13. A three-dimensional configuration of the 10 "central" artifact classes from Pincevent produced by their multidimensional scaling with the AVDISTLP1 similarity coefficient. The configuration is shown in perspective, using the same scaling factor for each dimension.

First, information from the 10-type MDS solution, which probably reflects the relationships among the central types more accurately, was used to cluster them. This result was then taken as a starting structure for clustering the remaining types with themselves and the clusters of central types, using information from the 23 type MDS solution.

Fine-scale clustering with OVERCLUS. The first stage of clustering, involving only the 10 central types, was achieved using the OVERCLUS approach. The stimulus coordinates for the 10 types in 3-dimensional scaled space (Table 14) were used to calculate a 10 x 10 matrix of Euclidean distances among all combinations of the types in that space (Table 15). This matrix is a "smoothed" representation of the matrix of average local polythetic distances among types (AVDISTLP1 coefficients; Table 11); those inconsistencies among the coefficients that are not expressible in 3 dimensions or less have been removed by the MDS operation. The amount of inconsistency smoothed from the matrix of AVDISTLP1 coefficients is $1 - R^2$, or 1.9% of the variation in the distances among all types in the full dimensional space. The matrix of Euclidean distances is also rescaled in mean and variance compared to the matrix of AVDISTLP1 coefficients, as a result of the MDS operations; thus the two cannot be compared directly.

The Euclidean distance coefficients in the smoothed matrix were used to link types sequentially in accord with OVERCLUS procedures involving a complete linkage criterion. Complete linkage was used because the data had already been smoothed by the MDS procedures and further smoothing using partial linkage was thought unnecessary. A list of types that link at each fusion step was

Table 13.14

Stimulus Coordinates for 10 "Central" Artifact Types in 3-Dimensional Scaled Space, Based on AVDISTLP1 Coefficients

	Dimension		
	1	*2*	*3*
Core	0.3020	−2.0773	−0.2606
Burin	0.3277	0.5162	−0.4198
Burinsp	−1.0527	−0.0667	0.5763
Bec	−0.9966	−0.1092	0.8210
Notch	−2.5571	0.5766	−0.0637
Backbl	−1.1592	−0.4322	−0.6820
Utblade	−0.1148	0.8271	−0.5814
Phal	1.2884	0.2359	−0.2551
Meta	1.8498	−0.1710	1.2654
Hfr	2.1124	0.7005	−0.4000

generated (partially reproduced in Table 16), as well as a graph of number of clusters vs. fusion (Fig. 14) and a plot of level of dissimilarity (Euclidean distance of fusion) vs. fusion step (Fig. 14).

It seemed appropriate to declare a *single* distance (artifact density) threshold for defining depositional sets. The relationships among the types reflected predominantly *one set of* hearth-oriented depositional patterns within the confines of an area approximately *uniformly constrained* in the availability of space, rather than multiple sets of depositional patterns in scattered areas of the habitation that have diverse spatial constraints. The threshold was determined using the previously discussed strategy involving prioritized, preferred characteristics of data representations at different fusion steps (p. 383). This strategy was realized as follows. 1) The plot of number of clusters vs. fusion step was made. This indicates several fusion steps/thresholds at which clusters inherent in the data crystallize and more simple organization is represented. These are the local minima or saddle points at steps 7, 14, 15, 16, 17, 18, 19, 20, 28, 29, and 30. 2) The plot of dissimilarity against fusion step was made. This plot indicates that of the fusion steps just mentioned, only some are preceded by

Table 13.15

Euclidean Distances among "Central" Artifact Types in 3-Dimensional Scaled Space, Based on AVDISTLP1 Coefficients

	Core	*Burin*	*Burinsp*	*Bec*	*Notch*	*Backbl*	*Utblade*	*Phal*	*Meta*	*Hfr*
Core	0.000	2.5985	2.5648	2.5942	3.9059	2.2403	2.9516	2.5147	2.8911	3.3186
Burin	2.5985	0.0000	1.7993	1.9195	2.9073	1.7830	0.5644	1.0142	2.3725	1.7943
Burinsp	2.5648	1.7993	0.0000	0.2546	1.7569	1.3146	1.7375	2.5027	2.9850	3.3999
Bec	2.5942	1.9195	0.2546	0.0000	1.9205	1.5459	1.9029	2.5492	2.8815	3.4369
Notch	3.9059	2.9073	1.7569	1.9205	0.0000	1.8314	2.5091	3.8653	4.6633	4.6832
Backbl	2.2403	1.7830	1.3146	1.5459	1.8314	0.0000	1.6391	2.5728	3.5937	3.4736
Utblade	2.9516	0.5644	1.7375	1.9029	2.5091	1.6391	0.0000	1.5572	2.8752	2.2382
Phal	2.5147	1.0142	2.5027	2.5492	3.8653	2.5728	1.5572	0.0000	1.6711	0.9570
Meta	2.8911	2.3725	2.9850	2.8815	4.6633	3.5937	2.8752	1.6711	0.0000	1.8979
Hfr	3.3186	1.7943	3.3999	3.4369	4.6832	3.4736	2.2382	0.9570	1.8979	0.0000

Table 13.16

List of Clusters of Artifact Types at Select Fusion Steps for the Analyis of "Central" Artifact Types, Based on AVDISTLP1 Coefficients

Fusion Step	*Completely Linked Artifact Types*	*Dissimilarity*
Step 14	1. burinsp-notch	1.7993
	2. burinsp-bec-backbl	
	3. burinsp-backbl-utblade-burin	
	4. burin-utblade-phal	
	5. burin-phal-hfr	
	6. phal-meta	
Step 15	1. notch-burinsp-backbl	1.8314
	2. burinsp-bec-backbl	
	3. burinsp-backbl-utblade-burin	
	4. burin-utblade-phal	
	5. burin-phal-hfr	
	6. phal-meta	
Step 16	1. notch-burinsp-backbl	1.8979
	2. burinsp-bec-backbl	
	3. burinsp-backbl-utblade-burin	
	4. burin-utblade-phal	
	5. burin-phal-hfr	
	6. phal-meta-hfr	
Step 17	1. notch-burinsp-backbl	1.9029
	2. bec-backbl-burinsp-utblade	
	3. burinsp-backbl-utblade-burin	
	4. burin-utblade-phal	
	5. burin-phal-hfr	
	6. phal-meta-hfr	
Step 18	1. notch-burinsp-backbl	1.9195
	2. bec-backbl-burinsp-utblade-burin	
	3. burin-utblade-phal	
	4. burin-phal-hfr	
	5. phal-meta-hfr	
Step 19	1. notch-burinsp-backbl-bec	1.9205
	2. bec-backbl-burinsp-utblade-burin	
	3. burin-utblade-phal	
	4. burin-phal-hfr	
	5. phal-meta-hfr	
Step 20	1. notch-burinsp-backbl-bec	2.2382
	2. bec-backbl-burinsp-utblade-burin	
	3. burin-utblade-phal-hfr	
	4. phal-meta-hfr	

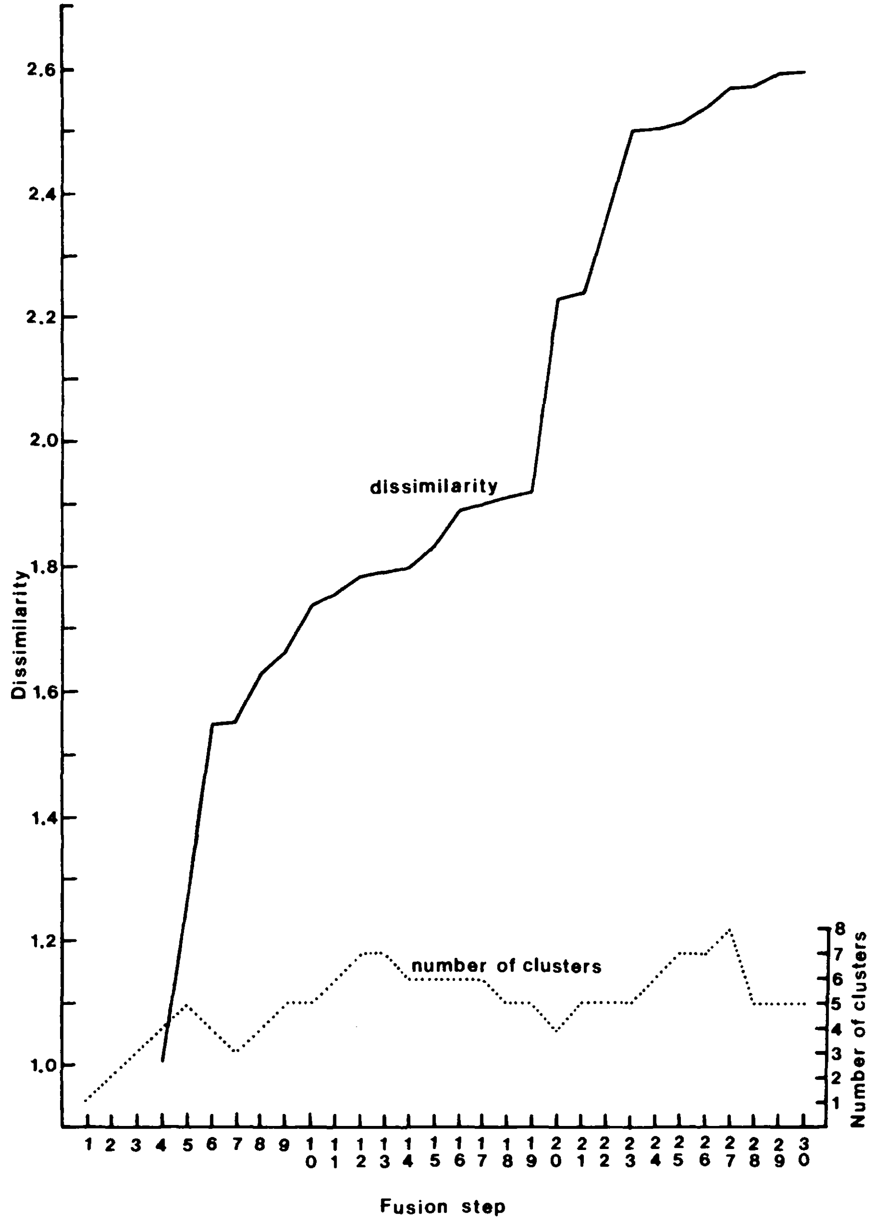

Fig. 13.14. Plots of number of clusters against fusion step and of dissimilarity against fusion step for an OVERCLUS analysis of the 10 "central" artifact types at Pincevent. The analysis is based on a matrix of Euclidean distances among the types that represents AVDISTLP1 coefficients smoothed by multidimensional scaling procedures.

the slight rises in dissimilarity which would suggest that the clusters that have crystallized are also relatively homogeneous. These steps include 14, 15, 16, 17, 18, 19, 28, 29, and 30. 3) Given the structural indeterminancy of the data set, the lists of grouped types for each of the latter array of fusion steps were inspected in order to determine stopping points that were preferable from an interpretive standpoint in two ways. (a) The stopping point generally defines and segregates groups of types that one might expect to be members of the same or different depositional sets, on the basis of the activities implied by the types (Table 8) and the context of deposition—here, possibly agglomerated or extremely overlapping activity areas (Speth & Johnson, 1976). (b) The stopping point defines groups that give insights into depositional set compositions and that imply activity organization or formation processes that, through plausible, might not otherwise have been discovered. These two criteria allowed the selection of a distance threshold of 1.8979 at fusion step 16. The resultant depositional sets for that step are shown in Table 16.

The clusters of types defined at fusion step 16 have two preferred characteristics in line with the criteria just cited. First, two certainly distinct activity sets become fully defined only by step 16. One set is suggestive of bone/antler/ivory/wood working, and more particularly, projectile point rearmament. It is composed of burin-burinsp-blackbl-utblade. The second set is suggestive of broth making and marrow boiling. It is composed of phal-meta-hfr. Although these groups also overlap at this step, some overlap is expectable, given their concentration around the hearths. (In fact, the degree to which they segregate at step 16 offers surprising resolution. This clarity decreases from step 20 onward.) Second, possibly subtle, unsuspected differences in the use of becs, notches, and burins—all broadly useful in working bone, antler, ivory, or wood—are indicated at step 16 by their membership in separate (though overlapping) sets. These distinctions fade in step 17 (where becs join burins) and again in step 19 (where notches join becs).

Broader-scale clustering. The second stage of clustering involved linking the 12 more peripheral types (and rib) to each other and the depositional sets formed previously. It was thought appropriate that the distance (artifact density) thresholds used to define depositional sets of these types be allowed to be higher and more variable than that applied to the central types. Many of the peripheral types (8 of 12) were most numerous in stata away from the hearths, where the availability of work space would have been less constrained and more variably constrained than work space around the hearths. The second stage of clustering was achieved as follows.

1) Potential groupings of peripheral artifact types with themselves and/or central artifact types were defined. This was done on the basis of their spatial relationships within the 23 type, 3-dimensional scaled configuration (Fig. 12) and the common activities that those relations might imply, and regardless of the magnitude of the distance threshold implied. These groups included scrapa-

microp-scrapbc (a potential hide working set); mandib-maxill-antler (all of the head region); scapula-hfr-antler (all sources of bone for making tools); rib-tibio-phal-meta-hfr (all involved in broth making, oil distilling, or eating); and bead-vert-ivory-pierce (all distant from the remaining artifacts).

2) A single distance threshold for the 23 type MDS solution, approximately analogous to that proposed in the 10-type solution, was defined by specifying a distance as large as the most distant intra-cluster relationships defined significant in the 10-type solution. This threshold was found to be 1.0966. It differs from the distance threshold for the 10-type solution (1.8979) largely because of the different scalings produced by the two MDS analyses.

3) To obtain a "first approximation" of clusters of peripheral types or peripheral and central types, the threshold of 1.0966 was applied to them. Those peripheral types that joined at or below this threshold with other peripheral or central types on a complete linkage basis were considered depositional sets for certain. Sets 4, 7, 8 through 15, and 17 listed in Table 17 were defined in this manner. These sets include a number of the relationships thought potentially significant and listed above (e.g., microp-scrapa; microp-scrapbc; maxill-mandib).

4) In line with the higher and more variable distance thresholds presumed appropriate for the peripheral types (above), the single threshold defining the tentative clusters was raised for some clusters, allowing the admittance of additional types to them on a complete linkage basis. Each new threshold was defined in accordance with certain strict stipulations. (a) As before, the threshold preferably should define and segregate groups of types that one might expect to be members of the same or different depositional sets, on the basis of the activities implied by the types (Table 8), e.g., the potential groups listed in point 1, above. (b) As before, the threshold might define groups that give insights into depositional set composition and that imply activity organization or formation processes which, though plausible, might not otherwise have been discovered. (c) A threshold chosen so as to define a logical group should not involve relationships among types that are inconsistent with the complete linkage criterion of the OVERCLUS procedures. For example, suppose type *A* is most closely related to type *B*, then *C*, and distantly related to *D*; type *B* is most closely related to *A*, then *C*, and distantly related to *D*; but *C* is most closely related to *A*, *then D*, then *B*. Although a linkage of *A*, *B*, and *C* might seem meaningful from an *interpretive* standpoint, it would also imply, assuming a complete linkage structure, linkages of *A* to *D*, *B* to *D*, and *C* to *D*—the first two relationships of which are not suggested *structurally* by the data and additionally might not be meaningful from an interpretive standpoint. Thus, the set ABC, though attractive from an interpretive standpoint, would not be defined; only the linkages of *A* to *B*, *A* to *C*, and *C* to *D* would be defined. In this way, the structural constraint of complete linkage on grouping proved very restrictive, preventing group definition that was oriented primarily toward creating interpretable sets

Table 13.17

Depositional Sets Defined Using the Dissimilarity Coefficient AVDISTLP1 with Multidimensional Scaling and OVERCLUS Algorithms

Set	*Average Intertype Distance Threshold Used to Define Sets*[1]
1. burin burinsp utblade backbl[2]	1.0966
2. burinsp backbl bec[2]	1.0966
3. burinsp backbl notch[2]	1.0966
4. phal meta hfr rib[2,3] ssls (clustered component)[4]	1.0966
5. utblade burin phal[2]	1.0966
6. hfr burin phal[2]	1.0966
7. rib utblade phal hfr[3]	1.0966
8. tibio hfr[3]	1.0966
8. core tibio[3]	1.0966
10. microp scrapa[3]	1.0966
11. microp scrapbc[3]	1.0966
12. microp notch[3]	1.0966
13. maxill mandib burin core[3]	1.0966
14. mandib antler[3]	1.0966
15. scapula[3]	1.0966
16. ivory bead vert[3]	2.4538
17. ivory notch backbl burinsp[3]	2.4538
18. bead pierce[3]	1.6005
19. vert mandib[3]	2.4538

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[1] Relative to the 23-type multidimensional scaling solution as a standard.

[2] Group based on intertype relations in the 10-type multidimensional scaling solution.

[3] Group based on intertype relations in the 23-type multidimensional scaling solution.

[4] The undissected ubiquitous, high density, clustered distribution of ssls items, as a whole, was included in the 10 and 23-type multidimensional scaling solutions. The association presumably results primarily from the clustered component of this distribution.

and that might otherwise have occurred in an overly zealous manner. Table 18 is a list of the types to which given peripheral types are closest, which was used in defining structurally consistent thresholds and preventing overly zealous clustering. (d) The threshold should not be made so large—for the sake of linking types that would seem to define a meaningful group—that the group overlaps extensively with many surrounding groups. Again, this constraint proved to restrict over-zealous clustering. Table 18 was used to check for this restriction, as well.

On the basis of these criteria for defining thresholds, and considering the relationships among peripheral and central types that were thought potentially significant (step 1, above), the peripheral types were clustered with each other and with the central types. The resulting depositional sets, 19 in all, are shown in Table 17.

Consideration of ubiquitously distributed artifact types. To the 19 depositional sets found using MDS and OVERCLUS procedures, two final sets can be added: one comprised of the ubiquitously distributed artifact *class*, flint pebbles, and the second comprised of the ubiquitous *component* of the complex, widely-scattered artifact class, sandstone-limestone. These ubiquitous scatters are obviously different in their arrangement from the distributions of the other, nonubiquitous types. They also differ visibly from each other. The ubiquitous flint distribution has small, tight clusters of a few items each here and there; such minor clusters are not as common in the ubiquitous component of the ssls distribution.

Within the composite ssls distribution, there is a clearly clustered component composed of many items surrounding the hearths additional to the lighter-scatter, ubiquitous component. By introducing ssls, alone, into the 10-type, 3-dimensional MDS solution, it was found that the clustered component (presumably) of this type's distribution joined with only the types in set 4 below the 1.0966 threshold equivalent. The positions of the types other than ssls remained essentially stable in their positions with the introduction of ssls, which suggested the reliability of the new configuration. Diagnostic statistics for the augmented MDS solution are given in Table 12. No attempt was made to introduce flint into these solutions, given its more dispersed distribution over the site.

Interpretation of the Depositional Sets

In a routine spatial analysis, the process of interpreting the sets would involve considering both the activities implied by the artifact types defining the sets (Table 8) plus the spatial distributions of the sets. Because definition of multi-type spatial clusters of artifacts is beyond the scope of this chapter (see Carr, 1984 for applicable methods), the sets will be interpreted primarily on the former evidence. Spatial information will be limited to largely the hearth-oriented or nonhearth-oriented nature of the types (Table 13).

Table 13.18

List of Any Types to which Peripheral Types are Most Near in the 23-Type MDS Solution, Based on AVDISTLP1 Coefficients. Euclidean Distances between Types in 3-Dimensional Scaled Space are Shown

Tibio	*Rib*	*Microp*	*Scrapa*	*Scrapbc*	*Mandib*	*Maxill*	*Antler*	*Scap*	*Ivory*	*Pierce*	*Bead*	*Vert*
hfr 0.8650	utblade 0.6848	scrapbc 0.9940	microp 1.0188	microp 0.9940	burin 0.8337	core 0.8112	mandib 1.0683	tibio 1.3921	vert 2.1169	bead 1.6005	pierce 1.6005	bead 2.0252
core 1.0622	phal 0.7955	scrapa 1.0188	scrapbc 1.4845	utblade 1.2553	core 0.9627	burin 0.8875	burin 1.6601	antler 1.8651	notch 2.2353	antler 2.2883	vert 2.0252	ivory 2.1169
burin 1.1506	hfr 0.9252	notch 1.0698	notch 1.8885	rib 1.3499	maxill 1.0549	mandib 1.0549	core 1.7083	scap 2.1048	burinsp 2.3724	mandib 2.3939	ivory 2.4538	mandib 2.4444
meta 1.1561	meta 1.0416	backbl 1.2357	backbl 2.0434	backbl 1.3747	antler 1.0683	burinsp 1.1185	tibio 1.7842	hfr 2.2028	backbl 2.3957	backbl 2.4034	mandib 3.0371	burinsp 2.7222
utblade 1.1761	tibio 1.2051	bec 1.3120	bec 2.2700	tibio 1.4169	burinsp 1.3146	phal 1.2738	scap 1.8651	core 2.2979	bead 2.4538	notch 2.5723	backbl 3.0835	maxill 2.7563
rib 1.2057	core 1.3436	utblade 1.3802	utblade 2.3489	notch 1.4445	backbl 1.3728	bec 1.2770	maxill 1.9704	burin 2.3107	bec 2.6116	burin 2.8098	notch 3.1621	backbl 2.8761
phal 1.2936	scrapbc 1.3499	burinsp 1.5971	rib 2.4908	scrapa 1.4845	bec 1.4061	meta 1.3715	hfr 2.1985	maxill 2.3954	microp 2.9489	scrapbc 2.8618	antler 3.2169	pierce 2.8810
scap 1.3921	bec 1.4144	rib 1.6262	burinsp 2.5265	bec 1.4901	tibia 1.6344	hfr 1.4184	backbl 2.2038	meta 2.4714	mandib 3.0382	vert 2.8810	burinsp 3.3514	notch 2.9501
scrapbc 1.4169	burin 1.4397	burin 1.9064	burin 2.8092	burin 1.6678	notch 1.6564	utblade 1.4433	pierce 2.2883	rib 2.4822	pierce 3.0919	burinsp 2.8887	bec 3.5208	antler 2.9920
mandib 1.6344	microp 1.6262	phal 2.0609	tibio 2.8869	core 1.7848	utblade 1.6871	backbl 1.6045	burinsp 2.3239	utblade 2.4942	burin 3.1094	bec 2.8944	burin 3.5697	burin 3.0200
bec 1.6488	burinsp 1.7258	core 2.0649	core 2.9896	burinsp 1.8374	hfr 1.7455	notch 1.7682	bec 2.3265	phal 2.6822	maxill 3.1417	scap 2.9810	maxill 3.8093	bec 3.0422
backbl 1.7600	backbl 1.7524	tibio 2.1570	scrapa 3.0347	hfr 1.8677	phal 1.8447	tibio 1.8427	meta 2.3717	backbl 2.7167	scrapa 3.3048	core 3.0551	core 3.8261	core 3.1966

Set 1. Several interpretations of this association of artifact classes are possible. (a) All of the classes—burins, burin spalls, utilized blades, and backed bladelets—have in common their generalized possible use in or production in the graving, boring, or whittling of bone, antler, ivory, or wood (Table 8). In this case, their association would reflect the common activity in which they were used together or produced as refuse. (b) Alternatively, the association of backed bladelets which could have functioned as armatures on bone-splinter projectile points, with burins and utilized blades which are useful in the groove-and-splinter technique of bone working, could suggest the more particular activity of producing or rearming projectile points. The occurrence of this set around the hearths, where mastic for applying armatures to projectile points could have been melted, also supports this particular interpretation. As in the first interpretation, the association would reflect the common activity in which the artifact classes were used together or produced as refuse. (c) Burins are tools that sometimes were hafted for use (Keeley, personal communication, 1983). If burins were hafted using mastic just as backed bladelets would have been as armatures, the association of these two classes might in part represent the common hearth locations where tools were rehafted. In this case, the association would not represent tools used together in the same activity; rather, it would indicate only the common locations of their maintenance. This interpretation does not explain the association of utilized blades and burin spalls with burins and backed bladelets, and thus, can only supplement other interpretations of the set, at best. (d) Both utilized blades and some backed bladelets could have been used for a much wider range of tasks, such as cutting meat, hides, or plant material, as well as working wood, bone, antler or ivory. In this case, the association of the artifact classes in the set would represent the use of the same space for several kinds of activities. This is not unlikely, given the concentration of this set around the hearths, where lighted and heated work space presumably was valued and used for multiple purposes and where at least cooking tasks, in addition to the working of bone, antler, or wood, would have occurred.

All told, this depositional set could have been produced by one, several, or all of the processes just described. If one depositional process was involved, the production or rearmament of projectile points is most parsimonious and is thought most likely (Keeley, personal communication, 1983). The remains appear to represent primary refuse, given that the set includes burin spalls—small items that could comprise a drop zone (Binford, 1978, p. 345) and that would not easily be swept away.

Set 2. The common possible uses of the tools in this set include boring and whittling bone, antler, or ivory. Alternatively, the association could represent the spatial overlap of areas in which bone, antler, or ivory were worked using becs and burins, with areas in which projectile points were produced or rearmed. Again, the occurrence of burin spalls in this set suggests primary refuse. This interpretation is supported by the fact that heavy concentrations of becs, backed bladelets, burins, and burin spalls occur around two large stone blocks adjacent to hearths 2 and 3, which presumably were used for sitting while working (Leroi-Gourhan & Brézillon, 1966, p. 364) and around which debris and exhausted tools were dropped.

Set 3. The common possible functions of these tools include working bone, antler, ivory, or wood. More specifically, the occurrence of notches which are useful in shaving dart or arrow shafts, with backed bladelets which could have functioned as projectile point armatures, suggests the production of whole darts or arrows (shafts and points) rather than simply the rearmament of points. Alternatively, the set could represent the spatial overlap of areas of more generalized working of bone, antler, ivory, or wood, involving notches and burins, with areas where points were rearmed. Finally, given the location of the set primarily around the hearths, where foot traffic presumably was heavy, some notches might be simply blades that have been trampled and misidentified as notches. In this case, the set would represent a spurious manifestation of Set 1; all types within the set would occur in Set 1.

Set 4. All of the bones, save ribs, in this set are useful for making either broth or bone grease by stone boiling (citations and evidence in Table 8). This interpretation makes sense, given the concentration of items of these types around the hearths, as well as their association with sandstone and limestone rocks possibly used in stone boiling. Ribs were presumably eaten around the hearths, their occurrence within the set reflecting the spatial overlap of cooking and eating activities. It also is possible that the long bones, hfr, represent bone material used in making bone items, this activity having overlapped with eating and cooking around the hearths, as suggested by the next three sets.

Sets 5, 6, 7. These sets have members from both Sets 1 and 4 and represent their partial overlap.

Set 8. The long-bones in this group could have been used for making either bone grease around the hearths or bone artifacts in more peripheral strata, or both. The linking of tibio with hfr might suggest that the classification of tibio-peroneals separate from humeri, femurs, and radio-cubitals was a poor decision. The separation of tibio from hfr in Set 4, however, would suggest the opposite conclusion.

Set 9. The association of core and tibio could represent primary refuse from the manufacturing of blades to work bone, or more probably, the spatial overlap of knapping areas and bone grease preparation areas around the hearths. The use of tibia in the blade manufacturing process, itself, is not likely, given the usual manner of blade preparation by punch and hammer or pressure crutch techniques (Crabtree, 1968).

Sets 10, 11. The most parsimonious interpretation of this association is the common use of micropiercers and scrapers in working hide. The micropiercers would have been used to pierce holes in hides, either in the process of sewing them after their curing or to hold them in position during the final graining process. It is possible that some of the debris-free areas within the tents were areas where smaller pieces of hide were tacked and grained, rather than sleeping areas: many of the micropiercers and scrapers occur around the edges of the debris-free zones.

The fact that scraper types *A* and *BC* both associate with micropiercers but not with each other might be used to support the idea that these two kinds of scrapers, which differ in edge angle, were used for defleshing vs. graining hides, respectively. The two activities would have occurred in different locales but involved micropiercers in common. However, this does not seem likely, given the distribution of the possible defleshers *within* the huts and the messiness of defleshing hides, which normally would be done outdoors, weather permitting.

Alternatively and preferably, the two different distributions of scrapers and micropiercers might reflect a change in space-use over time. The scrapbc (high edge angle)-micropiercer distribution would indicate locations used earlier in the occupation and where exhausted scrapers were abandoned. The scrapa (low edge angle)-micropiercer distribution would indicate locations used later and where only partially depleted scrapers were left at site abandonment.

Finally, it might be argued that the association of micropiercers and scrapers of either kind reflects only the spatial overlap of two distinct activities: wood/bone boring (microp) and hide working (scrapers). Although this alternative cannot be negated, it does not seem as probable. Both types in the set tend to occur away from the hearths, where available work space was less constrained and overlap of activities was less likely.

Set 12. Micropiercers appear to have been used to work not only hide, but also bone, antler, ivory or wood, given their association in this set with notches. The micropiercers might have been used to obtain splinters of bone or wood from larger pieces of these raw materials, the splinters having then been rounded with notches. They might also, or alternatively, have been used to groove the lengths of dart shafts after the shafts were rounded with notches—a functional shaft design used by some American Indians (Winters, 1969, p. 54)—or to groove-decorate other items rounded with notches.

Set 13. This set is composed of artifact types that concentrate around the hearths: mandibles, burins, and cores. It might represent the spatial overlap of several unrelated activities around the hearths: bone grease making, bone/antler/ivory working, and knapping, respectively. The meaning of the occurrence of maxilla in the set is unclear.

Set 14. Both of the types in this set—antler and mandibles—are reindeer head parts that might have served as raw material sources. The association derives primarily from their coarrangement *outside* the huts (Strata 5, 9). Here, a few burins also occur, which might have been used to extract splinters of these raw materials. In this case, the association would be considered primary refuse left behind from an activity. However, the association could equally represent a secondary refuse deposit, dumped outside one of the hut entrances.

Set 15. Scapulae occur primarily outside the huts (Strata 12, 13, 5, 9), where they appear to have been deposited as refuse. Their location in areas separate from the head parts and appendages of the reindeer indicates that different reindeer parts were probably processed in different locales as well as deposited separately.

Set 16. The association of beads for personal adornment with ivory which might be made into similarly personal items is reminiscent of other such associations of personal belongings elsewhere in Pincevent (Leroi-Gourhan & Brézillon, 1966, p. 361). The occurrence of vertebrae in this set may represent a spurious association, given the small number of items (of each type) upon which the association is based.

Set 17. The association of notches, backed bladelets, and burin spalls with ivory—all hearth-concentrated types—suggests their common use in the working of ivory around the hearths. Alternatively, if the backed bladelets represent armatures on projectile points rather than tools for working ivory, the association could represent the spatial overlap of areas of ivory working—where notches, burins, and ivory were used—with areas of point armament. This interpretation is quite possible, given the locus of this set around the hearths, where work space was limited and probably used for multiple purposes. The remains would appear to represent primary refuse, given that the set includes burin spalls, which are harder to sweep.

Set 18. This set of beads and piercers may represent a spurious association produced by (a) the use of cell-centered positions for the items of both of the types, causing one item of each type to exactly coincide in one cell, and (b) the low number of items of both types (2 beads, 4 piercers). However, items of the two types do repeatedly occur in close proximity, and the piercers would have been appropriate in their tip diameters for drilling the holes in the carbon beads.

Set 19. This set is composed of reindeer vertebrae and mandibles that were dumped primarily outside of one of the hut's entrances (Strata 5 and 9), just as the head parts of Set 14 may have been. It is not known whether the vertebrae come from the neck region of the reindeer, but if so, then the two sets possibly represent a common depositional pattern for similar body parts.

Set 20. Alluvial flint pebbles, alone, comprise this set. Some of the items obviously were carried to the site and/or positioned within it by human forces, as evidenced by their size or clustering with artifacts. Many of the smaller items, however, may be natural alluvial inclusions (Leroi-Gourhan & Brézillon, 1966, p. 325), which gives the distribution of pebbles its ubiquitous characteristic.

Set 21. The ubiquitous component, alone, of the ssls distribution comprises this set. The clustered component was assigned to Set 4. Whereas the clustered component probably reflects primary deposition, around the hearths, of stones used in stone boiling (see Set 4), the ubiquitous component may represent secondary refuse deposition that involved the removal of heat-degraded stones from the hearth areas and the dumping of them in scattered locations away from the hearths and huts. Thus, we may see here an example of two components of the distribution of a single artifact class representing two different kinds of formation processes.

Broader Interpretations

The depositional patterns, formation processes, and activities reconstructed thus far would normally be explored further with plots of the spatial distributions of the several sets of artifact types. This would be done in order to infer patterns of interaction among social segments, population size and composition, site length of occupation, regional mobility patterns, and other states of variables of the behavioral-environmental system under examination.

Given the focus of this chapter, this step will not be taken. However, it is desirable to summarize some important conclusions and implications of the above analysis, which go beyond the reconstruction of depositional sets. Some of these approach this secondary level of synthesis. 1) The study of artifact class associations provides several kinds of information about artifact function not apparent from the list of types, their morphology, or their individual arrangements. (a) It helps resolve the ambiguity of the functions of several artifact classes and allows a more limited range of functions or a single function to be assigned to each class (e.g., scrapers for working hide rather than hide *or* wood/bone/antler). (b) It suggests functions that were not immediately suggested for some morphological classes. While burins are generally thought of as tools for boring or graving bone or antler (Keeley, 1978, p. 81; personal communication, 1983), the associations in Set 17 suggest their use on ivory, as well. [Use-wear from ivory is nearly indistinguishable from that from antler (Keeley, personal communication).] (c) The study suggests possible subtle differences in the uses of burins and becs, whereas recent interpretations of their function, based on use-wear analysis, have emphasized the equivalency of their use in boring bone or antler (Keeley, 1978, p. 81), albeit, to overcome traditional typological biases.

2) The analysis provides insight into the process of butchering and use of reindeer. Three different classes of animal parts have different depositional patterns, which suggests their different handling: appendages and abdomen (Set 4), shoulder girdle (Set 15), and head parts (Sets 13, 14, 19). The first class was used and deposited intensively around the hearths, in the process of cooking meat and making broth and bone grease. The latter two classes were deposited peripheral to the hearths and/or huts.

3) The analysis supports the conclusion (pp. 389-390) of a fairly short length of occupation. The clarity with which depositional sets from different activities around the hearths could be resolved (Sets 1, 2, 3, 4), yet their overlapping membership, suggests the operation of formation processes that would have led to a single, blurred palimpsest with an extensive length of stay.

EXPERIMENTAL INVESTIGATIONS OF THE BEHAVIORS OF THE NEW TECHNIQUES USING THE PINCEVENT DATA

To reach a better understanding of the behaviors of the several AVDIST coefficients and MDS procedures in response to data structures, the same distributional data were analyzed using the AVDISTGM and AVDISTGP coefficients and scaled in 6 dimensions through 1 using monotonic MDS procedures, as above. Both 10-type solutions for the central types, and 23-type solutions for the central and peripheral types combined, were calculated. An additional 10-type solution augmented with the two ubiquitous types (flint, ssls) was also calculated—a procedure not recommended for normal analytic investigations but having heuristic value. The distance matrices and statistics pertinent to these analyses are shown in Tables 19 through 22. On the basis of these results, several studies of the behavior of the coefficients and MDS procedures were made, as follows.

Effects of Incongruencies between Relevant Data Structure and the AVDIST Coefficients

It has been argued that the techniques used to analyze a spatial data set must be congruent with its relevant relational structure to obtain accurate results. Four AVDIST coefficients have consequently been proposed for analyzing four different relevant relational data structures, in which coarrangements among artifact types are organized in different ways along the monothetic-polythetic dimension (Models 1, 4, 5, 6 of Fig. 4). However, the particular effects of using the wrong coefficients to analyze data structures that are incongruent with them remain to be discussed and illustrated.

In preparation for this discussion, it must be noted that correct assessment of the organization of a number of artifact types into a depositional set, relative to other artifact types, depends on correct measurement of two kinds of relationships among types. These are 1) relationships between artifact types within the set, and 2) relationships of artifact types in the set to those not. In other words, both relationships of *internal cohesion* and those of *external isolation*, which help define a depositional set, must be correctly measured. If a coefficient underestimates or overestimates the strength of either of these two kinds of relationships, depositional set organization will not be accurately reflected, and the set may not be accurately determined in higher-level, multitype analysis.

In the following study, the accuracy of measurement of only the first kind of relationship is considered. It is asked how the accuracy of a coefficient in measuring the *degree of coarrangement* of two coarranged types is affected by the coefficient's assumptions about form of coarrangement compared to the types' actual form of coarrangement. Not considered is the accuracy of a coefficient in measuring the *degree of spatial segregation* of two dissimilarly arranged types, as a function of the assumptions it makes about form of spatial segregation (implied by its assumptions about form of coarrangement), compared to the types' actual manner of dissimilar arrangement. Thus, any conclusions drawn on the effects of incongruence between the assumed and actual forms of coarrangement of *two* types must be translated only with caution into conclusions on the accuracy of definition of depositional sets in higher-level, *multitype* analysis.

Predictable effects of inappropriate application of the AVDIST coefficients. From this perspective, several expectations can be posed about the effects of using the AVDIST coefficients to analyze data with which they are not congruent.

1) The AVDISTGM distance between two coarranged types will be excessively high if the types are coarranged in any of the forms of organization in Models 2 through 6. In these cases, the coefficient assumes more regularities in the magnitude and direction of asymmetry of the two types among strata than occur in the data. Depositional sets organized as in Models 2 through 6 consequently will not be defined as strongly by this coefficient as they might be by more congruent coefficients.

2) The AVDISTLP1 distance between two coarranged types will accurately reflect their degree of similar arrangement if the types are coarranged in any of the forms of organization in Models 1 through 4. In these circumstances, the coefficient assumes less constraining or equivalent characteristics of coarrangement than those expressed in the relationships among the types. This does not mean, however, that the coefficient will accurately measure the degree of segregation of types falling in different depositional sets that are organized like the more constrained Models 1, 2, and 3, or that it will lead to an accurate determination of such sets in higher-level, multitype analysis.

3) The AVDISTLP1 distance between two coarranged types organized in the form of Models 5 or 6 will be excessively high. In this case, the coefficient assumes the occurrence of both types in each stratum where one type occurs, whereas the coarranged types exhibit a less constrained organization, where some strata may have only one of the types. As a consequence, depositional sets organized as in Models 5 or 6 will not be defined as strongly by AVDISTLP1 as they might be by more congruent coefficients.

4) The degree of inflation of the AVDISTLP1 distance between types that are coarranged as in Models 5 or 6 may be either greater or less than the degree of inflation of the AVDISTGM distance between them, and thus, the AVDISTLP1 distance may be either greater or less than the AVDISTGM distance. This circumstance is not what one might initially expect from the relative degrees of discordance of the coefficients from the data.

Whether the AVDISTLP1 or AVDISTGM distance is more inflated and larger depends on the particular balance that occurs among several features of the data. The AVDISTLP1 distance will be more inflated and larger when (a) the number of strata having only one of the artifact types is high compared to the number of strata having both, (b) the number of items of the single type in the strata with only one type is high compared to the number of items in the

Table 13.19

Matrix of AVDISTGM Statistics Defined for Habitation No.1

	Core	*Burin*	*Burinsp*	*Bec*	*Pierce*	*Microp*	*Notch*	*Scrapa*	*Scrapbc*	*Backbl*	*Utblade*
Core	0.000	0.464	0.473	0.487	1.111	1.029	0.834	1.113	0.798	0.394	0.583
Burin	0.464	0.000	0.333	0.347	1.340	0.792	0.606	1.278	0.632	0.412	0.299
Burinsp	0.473	0.333	0.000	0.300	1.106	0.767	0.486	1.211	0.656	0.314	0.441
Bec	0.487	0.347	0.300	0.000	1.116	0.780	0.551	1.074	0.594	0.403	0.485
Pierce	1.111	1.340	1.106	1.116	0.000	1.548	1.439	1.873	1.656	0.922	1.439
Microp	1.029	0.792	0.767	0.780	1.548	0.000	0.784	1.043	0.706	0.759	0.755
Notch	0.834	0.606	0.486	0.551	1.439	0.784	0.000	1.361	0.561	0.513	0.693
Scrapa	1.113	1.278	1.211	1.074	1.873	1.043	1.361	0.000	1.416	1.018	1.176
Scrapbc	0.798	0.632	0.656	0.594	1.656	0.706	0.561	1.416	0.000	0.567	0.671
Backbl	0.394	0.412	0.314	0.403	0.922	0.759	0.513	1.018	0.567	0.000	0.437
Utblade	0.583	0.299	0.441	0.485	1.439	0.755	0.693	1.176	0.671	0.437	0.000
Bead	1.544	1.870	1.517	1.724	1.177	2.472	1.915	2.845	2.274	1.190	2.177
Ivory	1.701	1.479	1.219	1.339	1.648	1.642	1.242	1.877	2.207	1.444	1.897
Antler	1.280	1.176	1.262	1.341	1.409	1.791	1.260	2.238	1.449	1.420	1.289
Phal	0.542	0.298	0.448	0.493	1.877	0.946	0.815	1.334	0.728	0.531	0.402
Meta	0.700	0.489	0.648	0.648	2.355	1.173	1.058	1.682	0.925	0.793	0.575
Hfr	0.632	0.468	0.718	0.717	1.816	1.184	1.063	1.410	0.979	0.734	0.556
Tibio	0.565	0.602	0.695	0.806	1.765	1.102	0.972	1.564	0.880	0.624	0.647
Scap	1.101	1.305	1.387	1.471	1.780	1.802	1.750	1.718	1.455	1.211	1.350
Rib	0.631	0.439	0.631	0.606	1.901	0.814	0.939	1.121	0.828	0.737	0.441
Vert	1.762	1.789	1.607	1.744	1.757	2.673	1.758	3.255	2.641	1.671	2.325
Mandib	0.916	0.955	0.860	0.931	1.671	1.552	1.245	1.640	1.647	0.958	1.179
Maxill	0.665	0.669	0.802	0.665	1.373	1.325	0.886	1.698	1.266	0.745	0.826

	Bead	Ivory	Antler	Phal	Meta	Hfr	Tibio	Scap	Rib	Vert	Mandib	Maxill
Core	1.544	1.701	1.280	0.542	0.700	0.632	0.565	1.101	0.631	1.762	0.916	0.665
Burin	1.870	1.479	1.176	0.298	0.489	0.468	0.602	1.305	0.439	1.789	0.955	0.669
Burinsp	1.517	1.219	1.262	0.448	0.648	0.718	0.695	1.387	0.631	1.607	0.860	0.802
Bec	1.724	1.339	1.341	0.493	0.648	0.717	0.806	1.471	0.606	1.744	0.931	0.665
Pierce	1.177	1.648	1.409	1.877	2.355	1.816	1.765	1.780	1.901	1.757	1.671	1.373
Microp	2.472	1.642	1.791	0.946	1.173	1.184	1.102	1.802	0.814	2.673	1.552	1.325
Notch	1.915	1.242	1.260	0.815	1.058	1.063	0.972	1.750	0.939	1.758	1.245	0.886
Scrapa	2.845	1.877	2.238	1.334	1.682	1.410	1.564	1.718	1.121	3.255	1.640	1.698
Scrapbc	2.274	2.207	1.449	0.728	0.925	0.979	0.880	1.455	0.828	2.641	1.647	1.266
Backbl	1.190	1.444	1.420	0.531	0.793	0.734	0.624	1.211	0.737	1.671	0.958	0.745
Utblade	2.177	1.897	1.289	0.402	0.575	0.556	0.647	1.350	0.441	2.325	1.179	0.826
Bead	0.000	1.735	1.813	2.608	3.164	2.647	2.468	2.581	2.797	1.066	2.190	1.805
Ivory	1.735	0.000	2.242	1.906	2.476	2.328	2.503	3.044	2.416	1.694	1.927	1.531
Antler	1.813	2.242	0.000	1.240	1.318	1.234	1.186	0.856	1.335	1.532	1.368	1.035
Phal	2.608	1.906	1.240	0.000	0.355	0.368	0.664	1.220	0.377	2.393	0.968	0.716
Meta	3.164	2.476	1.318	0.355	0.000	0.399	0.645	1.255	0.437	2.855	0.922	0.762
Hfr	2.647	2.328	1.234	0.368	0.399	0.000	0.546	1.394	0.397	2.594	0.964	0.938
Tibio	2.468	2.503	1.186	0.664	0.645	0.546	0.000	1.276	0.593	2.634	1.316	1.134
Scap	2.581	3.044	0.856	1.220	1.255	1.394	1.276	0.000	1.187	2.447	1.590	1.370
Rib	2.797	2.416	1.335	0.377	0.437	0.397	0.593	1.187	0.000	2.952	1.286	1.074
Vert	1.066	1.694	1.532	2.393	2.855	2.594	2.634	2.447	2.952	0.000	1.932	1.525
Mandib	2.190	1.927	1.368	0.968	0.922	0.964	1.316	1.590	1.286	1.932	0.000	1.012
Maxill	1.805	1.531	1.035	0.716	0.762	0.938	1.134	1.370	1.074	1.525	1.012	0.000

Table 13.20

Matrix of AVDISTGP Statistics Defined for Habitation No. 1

	Core	*Burin*	*Burinsp*	*Bec*	*Pierce*	*Microp*	*Notch*	*Scrapa*	*Scrapbc*	*Backbl*	*Utblade*
Core	0.000	0.355	0.400	0.444	0.608	0.878	0.596	0.647	0.763	0.275	0.485
Burin	0.355	0.000	0.203	0.232	0.390	0.269	0.230	0.407	0.351	0.173	0.297
Burinsp	0.400	0.203	0.000	0.296	0.595	0.733	0.401	0.891	0.623	0.230	0.289
Bec	0.444	0.232	0.296	0.000	0.420	0.601	0.338	0.993	0.471	0.344	0.358
Pierce	0.608	0.390	0.595	0.420	0.000	1.000	1.212	1.518	1.194	0.861	0.548
Microp	0.878	0.269	0.733	0.601	1.000	0.000	0.693	0.985	0.700	0.701	0.302
Notch	0.596	0.230	0.401	0.338	1.212	0.693	0.000	1.327	0.550	0.505	0.240
Scrapa	0.647	0.407	0.891	0.993	1.518	0.985	1.327	0.000	1.293	0.871	0.445
Scrapbc	0.763	0.351	0.623	0.471	1.194	0.700	0.550	1.293	0.000	0.473	0.315
Backbl	0.275	0.173	0.230	0.344	0.861	0.701	0.505	0.871	0.473	0.000	0.235
Utblade	0.485	0.297	0.289	0.358	0.548	0.302	0.240	0.445	0.315	0.235	0.000
Bead	0.460	0.309	0.516	0.596	0.705	1.503	0.507	1.969	1.267	1.007	0.655
Ivory	0.902	0.329	0.531	0.383	1.302	0.785	0.607	1.223	1.148	0.808	0.441
Antler	0.881	0.606	1.236	1.284	1.062	1.552	1.093	1.881	1.145	1.394	1.122
Phal	0.377	0.281	0.233	0.281	0.603	0.508	0.258	0.423	0.408	0.251	0.340
Meta	0.384	0.441	0.397	0.393	0.674	0.618	0.394	0.452	0.457	0.416	0.501
Hfr	0.342	0.395	0.410	0.362	0.537	0.452	0.352	0.342	0.538	0.338	0.482
Tibio	0.466	0.592	0.482	0.665	0.806	0.760	0.546	1.178	0.489	0.443	0.619
Scap	0.791	0.628	1.345	1.415	1.292	1.549	1.617	1.623	1.247	1.131	1.254
Rib	0.393	0.420	0.348	0.314	0.729	0.278	0.320	0.255	0.348	0.369	0.356
Vert	1.076	0.855	1.561	1.625	1.621	2.473	1.617	3.098	2.619	1.629	1.607
Mandib	0.895	0.690	0.825	0.909	1.049	1.535	1.163	1.275	1.585	0.903	1.012
Maxill	0.542	0.349	0.781	0.662	1.058	1.175	0.728	1.170	1.245	0.693	0.632

	Bead	Ivory	Antler	Phal	Meta	Hfr	Tibio	Scap	Rib	Vert	Mandib	Maxill
Core	0.460	0.902	0.881	0.377	0.384	0.342	0.466	0.791	0.393	1.076	0.895	0.542
Burin	0.309	0.329	0.606	0.281	0.441	0.395	0.592	0.628	0.420	0.855	0.690	0.349
Burinsp	0.516	0.531	1.236	0.233	0.397	0.410	0.482	1.345	0.348	1.561	0.825	0.781
Bec	0.596	0.383	1.284	0.281	0.393	0.362	0.665	1.415	0.314	1.625	0.909	0.662
Pierce	0.705	1.302	1.062	0.603	0.674	0.537	0.806	1.292	0.729	1.621	1.049	1.058
Microp	1.503	0.785	1.552	0.508	0.618	0.452	0.760	1.549	0.278	2.473	1.535	1.175
Notch	0.507	0.607	1.093	0.258	0.394	0.352	0.546	1.617	0.320	1.617	1.163	0.728
Scrapa	1.969	1.223	1.881	0.423	0.452	0.342	1.178	1.623	0.255	3.098	1.275	1.170
Scrapbc	1.267	1.148	1.145	0.408	0.457	0.538	0.489	1.247	0.348	2.619	1.585	1.245
Backbl	1.007	0.808	1.394	0.251	0.416	0.338	0.443	1.131	0.369	1.629	0.903	0.693
Utblade	0.655	0.441	1.122	0.340	0.501	0.482	0.619	1.254	0.356	1.607	1.012	0.632
Bead	0.000	1.333	0.943	0.610	0.537	0.533	0.706	1.175	0.645	0.805	0.720	0.484
Ivory	1.333	0.000	1.497	0.517	0.648	0.524	0.811	2.106	0.420	1.373	0.990	0.496
Antler	0.943	1.497	0.000	0.722	0.775	0.625	0.999	0.752	1.125	0.747	1.353	1.031
Phal	0.610	0.517	0.722	0.000	0.342	0.334	0.616	0.509	0.365	0.954	0.426	0.540
Meta	0.537	0.648	0.775	0.342	0.000	0.366	0.617	0.876	0.420	0.589	0.477	0.434
Hfr	0.533	0.524	0.625	0.334	0.366	0.000	0.423	0.785	0.380	1.107	0.283	0.512
Tibio	0.706	0.811	0.999	0.616	0.617	0.423	0.000	0.798	0.398	1.677	0.817	0.722
Scap	1.175	2.106	0.752	0.509	0.876	0.785	0.798	0.000	0.714	0.839	1.517	1.174
Rib	0.645	0.420	1.125	0.365	0.420	0.380	0.398	0.714	0.000	1.731	0.791	0.649
Vert	0.805	1.373	0.747	0.954	0.589	1.107	1.677	0.839	1.731	0.000	1.179	0.602
Mandib	0.720	0.990	1.353	0.426	0.477	0.283	0.817	1.517	0.791	1.179	0.000	0.940
Maxill	0.484	0.496	1.031	0.540	0.434	0.512	0.722	1.174	0.649	0.602	0.940	0.000

Table 13.21

Partial Matrices of Distance Coefficients Relating Ubiquitous Types to Central Types

AVDISTLP1 Coefficients			*AVDISTGM Coefficients*			*AVDISTGP Coefficients*		
	Flint	*Ssls*		*Flint*	*Ssls*		*Flint*	*Ssls*
Core	0.759	0.572	*Core*	0.735	0.509	*Core*	0.388	0.137
Burin	0.481	0.381	*Burin*	0.565	0.363	*Burin*	0.355	0.154
Burinsp	1.204	1.158	*Burinsp*	1.087	0.664	*Burinsp*	0.354	0.173
Bec	1.235	1.222	*Bec*	1.046	0.644	*Bec*	0.433	0.153
Notch	1.675	1.905	*Notch*	1.341	1.034	*Notch*	0.369	0.201
Backbl	1.236	1.080	*Backbl*	1.078	0.649	*Backbl*	0.379	0.137
Utblade	0.858	0.771	*Utblade*	0.743	0.456	*Utblade*	0.343	0.180
Phal	0.622	0.430	*Phal*	0.577	0.383	*Phal*	0.345	0.192
Meta	0.436	0.413	*Meta*	0.585	0.447	*Meta*	0.370	0.258
Hfr	0.518	0.434	*Hfr*	0.504	0.436	*Hfr*	0.356	0.261
Flint	0.000	0.255	*Flint*	0.000	0.326	*Flint*	0.000	0.271
Ssls	0.255	0.000	*Ssls*	0.326	0.000	*Ssls*	0.271	0.000

strata with both types, (c) the distances between strata having only one type and their nearest strata with both types is great, and (d) asymmetry between types within strata with both types is great. Figure 15 illustrates the effects of changes in two of these factors (b and c).

5) The AVDISTGP distance between two types that are coarranged as in Models 1, 2, 3, or 5 will accurately measure their degree of coarrangement. In these cases, the coefficient assumes less constraining or equivalent characteristics of coarrangement than those expressed in the organization of the types. Again, this does not mean, however, that the coefficient will accurately measure the degree of segregation of types falling in different depositional sets that are organized like the more constrained Models 1, 2, or 3, or that it will lead to an accurate determination of such sets in higher-level multitype analysis.

6) The AVDISTGP distance between two types coarranged as in Models 4 or 6 will be excessively high, given the more constraining characteristics of coarrangement assumed by this measure compared to those within the data. In particular, the coefficient overstringently requires that the direction of asymmetry between two types remain uniform over all strata. Depositional sets organized as in Models 4 or 6 will correspondingly be less strongly defined by AVDISTGP than they might be by more congruent coefficients. The AVDISTGP distance will not be as inflated as the AVDISTGM distance, which is more restrictive in its requirements for coarrangement.

7) When two types are coarranged as in Model 6, the AVDISTGP distance

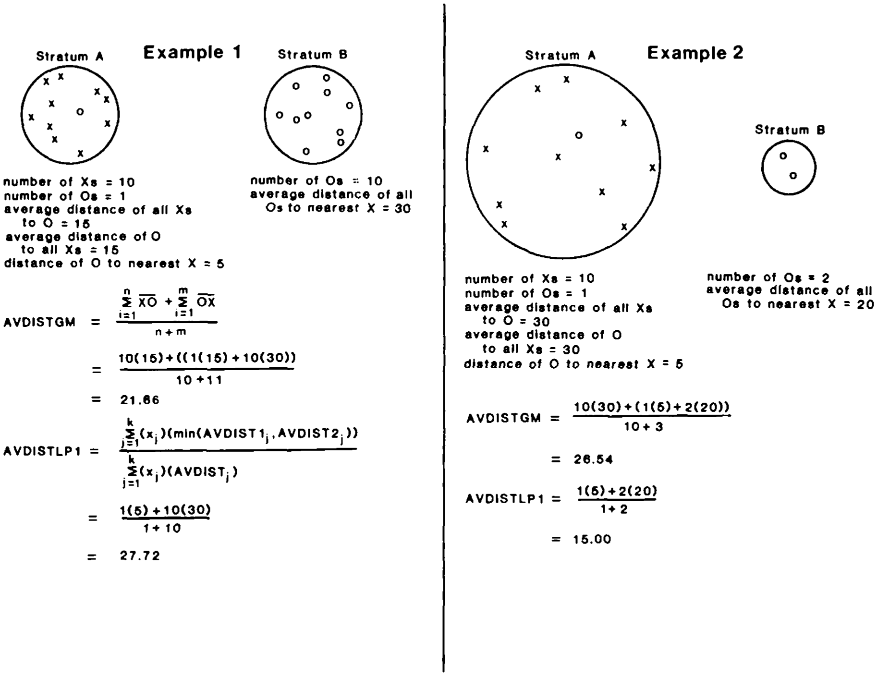

Fig. 13.15. AVDISTGM can be larger or smaller than AVDISTLP1 when both are discordantly applied to a Model 5 or 6 form of coarrangement of types. The magnitudes of the coefficients are not related to the degrees to which they are discordant from the data. Here, data examples 1 and 2 both illustrate two types that are coarranged in a Model 5 form. The coarrangements differ, however, in 1) the number of items of the type that sometimes occurs alone in clusters, for those clusters where it is alone, compared to the number of items of both types in strata having both types, and 2) the distances between strata having only one type and their nearest strata with both types. These factors affect the relative magnitudes of the two coefficients.

between them may be more inflated or less inflated than the AVDISTLP1 distance between them, and thus, the AVDISTGP coefficient may be larger or smaller than the AVDISTLP1 coefficient. Whether the AVDISTLP1 or AVDISTGP coefficient is more inflated and larger depends on the particular balance between several features of the data. A larger and more inflated AVDISTLP1 coefficient that AVDISTGP coefficient will be favored when conditions a-c (mentioned previously) occur, and when (d) among clusters, reversals in the direction of asymmetry between types are minimal.

8) The AVDISTLP2 distance between two types that are coarranged as in Models 1 through 6 will accurately reflect their degree of similar arrangement. However, the coefficient will not necessarily measure accurately the degree of

segregation of types falling in different depositional sets organized as in Models 1 through 5, nor will it necessarily lead to an accurate determination of such sets in higher-level, multi-type analysis.

Illustrating the effects of inappropriate application of the AVDIST coefficients. The effects of incongruency between a coefficient's assumptions and the form of a coarrangement can be illustrated with the Pincevent data. A number of artifact type-pairs having different patterns of asymmetry were chosen as *heuristic* examples of coarranged types organized as in Models 3 through 6, regardless of whether they were judged coarranged in the previous analysis (Tables 22, 23). All the pairs exhibit asymmetry of variable magnitude among strata, and vary in whether asymmetry changes in direction from stratum to stratum and

Table 13.22

Number of Items of Each Artifact Type within the Spatial Strata at Habitation No. 1

Artifact Type	*Stratum Number*													
	8	*9*	*10*	*11*	*5*	*6*	*16*	*12*	*13*	*14*	*H3*	*H2*	*H1*	*Total*
Core	2	1	0	0	4	0	0	2	1	0	24	9	5	48
Burin	7	1	0	0	1	12	1	1	0	7	31	43	16	120
Burinsp	0	0	0	0	0	9	0	0	0	1	28	21	9	68
Bec	2	0	0	0	0	4	0	0	0	1	14	19	5	45
Pierce	1	0	0	0	0	1	0	0	0	0	2	1	0	5
Microp	2	0	0	0	0	1	2	0	0	1	2	2	1	11
Notch	1	0	0	0	1	2	0	0	0	0	2	11	2	19
Scrapa	0	0	0	0	0	0	1	2	0	0	1	1	2	7
Scrapbc	5	0	0	0	0	0	0	0	0	1	5	6	1	18
Backbl	2	0	0	0	0	0	0	0	0	0	39	15	4	60
Utblade	6	0	0	0	0	8	1	1	0	2	26	20	9	73
Bead	0	0	0	0	1	0	0	0	0	0	1	0	0	2
Ivory	0	0	0	0	0	2	0	0	0	0	0	3	0	5
Antler	0	3	1	0	1	1	0	1	0	0	2	2	0	11
Phal	2	0	2	0	0	4	0	4	0	5	33	48	42	140
Meta	2	0	0	2	2	0	0	6	3	13	11	17	33	89
Hfr	6	0	1	0	4	3	1	20	0	8	13	23	14	93
Tibio	7	0	0	0	1	2	0	5	1	1	7	4	4	32
Scap	0	1	0	0	1	0	0	2	1	0	3	0	1	9
Rib	6	0	0	0	2	10	2	10	1	5	44	12	37	129
Vert	0	3	0	0	2	0	0	0	0	0	0	0	0	5
Maxill	0	0	1	0	1	1	0	1	0	2	2	0	1	9
Mandib	0	4	0	0	1	1	0	0	0	1	3	6	3	19

whether some strata have only one of the types, in accordance with the models. Minor exceptions of the arrangements of the pairs from the models of coarrangement they are taken to represent are shown in Table 23.

The values of AVDISTGM, AVDISTLP1, and AVDISTGP coefficients for the several pairs of types and the models they represent are shown in Table 24. The ordered relations among values of the different coefficients, for each pair representing each model of organization, all concord with the expectations discussed.

Some features in Table 24 that stress those behaviors of the coefficients that might not be expected initially from their design include the following. 1) The values of AVDISTLP1 and AVDISTGP for the pair representing Model 3 are exactly equivalent. Both coefficients accurately measure the degree of coarrangement of the types—despite the *different* assumptions they make about the organization of a coarrangement—because both make assumptions that are *less* restrictive than the data are constrained. This is not to say, however, that both coefficients would measure as equivalent the degree of segregation of types occurring in different depositional sets, or that such sets would be determined equally accurately using the two coefficients in a multi-type analysis.

2) The values of AVDISTLP1 (a more assuming coefficient) are sometimes larger, sometimes smaller than the values of AVDISTGM (a less assuming coefficient) for pairs representing Model 5, in accord with expectation 4, above. This illustrates that coefficients that are more constraining, in making greater numbers of restrictive assumptions about depositional set organization, do not necessarily give more inflated, inaccurate results than less constraining coefficients making fewer restrictive assumptions, when both are applied to data of an even less constrained form.

3) The values of AVDISTLP1 are all larger and more inflated than the values of AVDISTGM for the pairs representing Model 6 (though the reverse ordering also could have occurred). Again, this illustrates that the values taken by a coefficient and its accuracy are not necessarily a function of the number of constraining assumptions it makes, when applied to less constrained data.

The last two observations are very important in relation to the argument, which was made in the beginning of this chapter, about appropriate criteria for assessing the appropriateness of a technique for analyzing data. *An analytic technique can not be judged as appropriate or inappropriate, either generally or in relation to a specific data set, on the basis of the number of constraining assumptions about relevant data structure that it makes. The particular nature of the assumptions, and their degrees of congruence with the relevant form of organization of the data at hand, is what matters.*

Effects of Including Ubiquitous Types in Multidimensional Scalings Using Different AVDIST Coefficients

The effect of introducing ubiquitously, densely distributed artifact types into a multidimensional scaling of more spatially restricted types will vary with the distance coefficients that are used. AVDISTGM and AVDISTLP1 coefficients, which require both artifact types of a coarranged pair to always occur in strata where either one occurs, will tend to assess the ubiquitously distributed types as distantly related to the more spatially restricted types. When introduced in a scaling operation, the large coefficient values that relate the ubiquitous and spatially restricted types will produce a space-dilating effect in it. On the other hand, AVDISTGP and AVDISTLP2 coefficients, which allow artifact types to closely associate when they do not necessarily co-occur in every stratum where one of the types occurs, will tend to assess the ubiquitously distributed types as closely related to the spatially restricted types. When introduced in a scaling analysis, the small coefficient values that relate the ubiquitously and spatially restricted types will produce a space-contracting effect. The average, *global*, space-dilating effect or the average *global* space-contracting effect in any particular analysis will be scaled out of the final MDS configuration, but *local* variations in the degree of dilation or contraction from the global average will not.

The different space-dilating or space-contracting effects of adding ubiquitous types to a MDS analysis when using different AVDIST coefficients is suggested in Table 25. For each of the distance coefficients—AVDISTGM, AVDISTLP1, and AVDISTGP—the average of its values which relate each of the ten, spatially restricted, central artifact types to each other are shown. Contrasted with these values are averages of the distances of the ubiquitous types, flint and sandstone-limestone, to the central types, for the same coefficients. The average of the distances from the ubiquitous to the central types are higher than the average of the distances between only the central types for the AVDISTGM and AVDISTLP1 coefficients. Adding the former coefficient values to the latter when multidimensional scaling the data would produce a global, space-dilating effect with local ramifications. In contrast, for the AVDISTGP coefficient, the average of the distances from the ubiquitous to the central types is lower than the average of the distances between only the central types. Combining the former coefficients with the latter when scaling the data would produce a space-contracting effect, with local manifestations.

Multidimensional scalings of the 10 central types, and the 10 types augmented with the ubiquitous types, were made for each AVDIST coefficient. The relationships among types in optimal dimensional configurations (2 or 3-dimensions) for the original and augmented solutions were compared to each other for each of the three coefficients, in search of local ramifications of space dilation or contraction. Most relationships among the central types remained stable or changed only slightly with the addition of the ubiquitous types. However, for each of the three comparisons, repositioning of a few types proceeded to the point where the *composition* of sets was altered slightly.

For configurations having more than an optimal number of dimensions, introducing the ubiquitous types caused major repositionings of many central types. Most potential sets of central types within the original MDS solutions could not be recognized in the augmented solutions. This instability of the higher dimensional solutions is expectable. When data are configured in a space larger than that necessary to express their dimensions of variability, the configuration will express error in the data (Kruskal & Wish, 1978, p. 57), i.e., contradictions among the dissimilarities between entities. The AVDIST coefficients that describe the relationships of ubiquitous types to central, spatially restricted types imply relationships among the central types that are contradictory to (dilated or contracted compared to) those described by the coefficients that relate the central types to each other. In lower dimensions, these contradictions are smoothed considerably from the configuration, whereas in overly generous dimensions, they are not.

The practical conclusions to be drawn from this experiment are clear regarding the procedure of introducing artifact types with ubiquitous, clustered distributions into a MDS analysis in order to determine the relationships of their clustered components to other types. 1) It is not advisable to introduce more than one ubiquitous, clustered type at a time into a MDS analysis, particularly when the number of spatially restricted types in the original solution is small. 2) Determining the optimal number of dimensions for displaying a group of spatially-restricted types is crucial, particularly when one's purpose is then to introduce a ubiquitous type (and thus, coefficient contradiction) into the solution.

THE IMPORTANCE OF ACKNOWLEDGING ARTIFACT TYPE ASYMMETRIES AND POLYTHETIC ORGANIZATION IN SPATIAL ANALYSIS: ILLUSTRATION WITH THE PINCEVENT DATA

A key concept used in this chapter is asymmetry among artifact types within sets. By varying the direction, magnitude, and completeness of asymmetry relations allowed among artifact types within depositional sets over areas of different scales, it was possible to define the six models of depositional set organization along the monothetic-polythetic dimension (Table 2).

It is desirable to illustrate the extent to which spatial variation in the direction, magnitude, and completeness of asymmetry relations among types within sets can dominate the structure of an intrasite spatial data set. This will suggest the importance of acknowledging such variation when choosing techniques for analyzing intrasite data. Whallon's (1984) analysis of the Mask site, in which he documents vivid changes in the patterns of covariation among artifact types from areal stratum to stratum (Whallon, 1984, p. 257) possibly gives some indication of the extent to which changes in the magnitude and direction of asymmetry can occur among artifact types within sets from area to area of a site. However, most, if not all, of the artifact types included in that study appear to belong to *different* activity sets rather than the same (see p. 314). Consequently, the pattern of spatially variable correlations (and by implication, asymmetry relations) that were found among types appears pertinent to the

Table 13.23

Degree of Correspondence between the Characteristics of Arrangement of Pairs of Artifact Types and Characteristics of the Models of Coarrangement They are Taken to Represent

Model and Type Pair	*Model Characteristics and Strata Corresponding to Them*			*Deviations from the Model*
Model 3:	*Both types must occur in each cluster*	*Asymmetry may be of different magnitudes in different clusters*	*Asymmetry must be in the same direction in each cluster*	
bec-microp	strata 8,6,14,1,2,3	strata 6,1,2,3	strata 8,6,14,1,2,3	microp occurs alone in stratum 16
Model 4:	*Both types must occur in each cluster*	*Asymmetry may be of different magnitudes in different clusters*	*Asymmetry may be of different directions in different clusters*	
hfr-phal	strata 8,10,6,12,14,1, 2,3	no strata with same magnitudes of asymmetry	strata 8,5,16,12,14 vs. 10,6,1,2,3,	hfr occurs alone in strata 5 (4 items) and 16 (1 item)
hfr-rib	strata 8,5,6,16,12,14,1, 2,3	only strata 10 and 13 have the same magnitude of asymmetry	strata 10,5,12,14,2 vs. 6,16,13,1,3	hfr occurs alone in stratum 10 (1 item), rib occurs alone in stratum 13 (1 item)
Model 5:	*Types may occur alone in some clusters*	*Asymmetry may be of different magnitudes in different clusters*	*Asymmetry must be in the same direction in each cluster*	
burin-notch	burin alone in strata 9,16,12,14	only strata 9,12,16 have the same magnitude of asymmetry	strata 8,9,6,16,12, 14,1,2,3	none

burin-bec	burin alone in strata 9,5,16,12	only strata 9,5,16,12 have the same magnitude of asymmetry	strata 8,9,5,6,16, 12,14,1,2,3	none
bead-maxill	maxill alone in strata 10,6,12,14,1	only strata 10,6,12,13 have the same magnitude of asymmetry	strata 10,6,12,14, 1,3	none
bead-mandib	mandib alone in strata 9,6,14,2,1	only strata 6 and 14 have the same magnitude of asymmetry	strata 9,6,14,1,2, 3	none
Model 6:	*Types may occur alone in some clusters*	*Asymmetry may be of different magnitudes in different clusters*	*Asymmetry may be in different directions in different clusters*	
burinsp-backbl	backbl alone in stratum 8, burinsp alone in strata 6,14	no strata with same magnitude of asymmetry	strata 6,14,2,1 vs. 8,3	none
scapula-antler	scapula alone in stratum 13, antler alone in strata 10,6	only strata 10,6,13 have the same magnitude of asymmetry	strata 12,13,1,3 vs. 9,10,6,2	none
scrapa-scrapbc	scrapbc alone in strata 8,14, scrapa alone in strata 16,12	only strata 16 and 14 have the same magnitude of asymmetry	strata 8,14,3,2 vs. 16,12,3	none
scrapa-microp	microp alone in strata 8,6,14, scrapa alone in stratum 12	only strata 8 and 12, and 6 and 14, have the same magnitude of asymmetry	strata 8,6,16,14,3,2 vs. 12,1	none

Table 13.24

Examples of Artifact Pairs Fitting Certain Models of Artifact Coarrangement and the Average Distance between Them Using Different Algorithms

Model and Type Pair	*Algorithm*		
	AVDISTGM	*AVDISTLP1*	*AVDISTGP*
Model 3			
bec-microp	.78	.601	.601
Model 4			
hfr-phal	.368	.264	.334
hfr-rib	.397	.319	. 380
Model 5			
burin-notch	.606	.685	.230
burin-bec	.347	.341	.232
bead-maxill	1.190	2.722	.720
bead-mandib	1.805	2.056	.484
Model 6			
burinsp-backbl	.314	.327	.230
scap-antler	.856	.874	.752
scrapa-scrapbc	1.416	1.466	1.293
scrapa-microp	1.043	1.145	.985

external relationships (i.e., spatial overlap) among depositional sets more than to their internal organization. Moreover, covariation among types provides only an indirect measure of the magnitude and direction of asymmetry relations among types.

To more directly illustrate the internal organization of depositional sets in regard to asymmetry relations, the Pincevent data were examined for variation, among the defined spatial strata (Fig. 10), in the asymmetry occurring between those type-pairs which fall within the same depositional sets, as previously defined (Table 17). Analysis was focused on spatial variation in the *direction* of asymmetry among types and the magnitude of such asymmetry reversals, alone. The particular questions for which answers were sought are:

Table 13.25

Averages of AVDIST Coefficients Relating Central and Ubiquitous Artifact Types, Showing Space Dilating and Contracting Effects*

	AVDISTGM	*AVDISTLP1*	*AVDISTGP*
Average of distance coefficients relating central types.	.540 ± .183 (N = 45)	.592 ± .293 (N = 45)	.347 ± .091 (N = 45)
Average of distance coefficients relating ubiquitous types to central types.	.692 ± .278 (N = 20)	.870 ± .448 (N = 20)	.277 ± .101 (N = 20)

*Central types include: core, burin, burinsp, bec, notch, backbl, utblade, phal, meta, hfr. Peripheral types include: flint, ssls.

1) What is the *average magnitude of asymmetry reversals* between artifact types within the same depositional set?
2) How *common* are stratum-to-stratum reversals in the direction of asymmetry among types within the same depositional set?
3) Does spatial variation in the direction of asymmetry among types result from spatial variation in *formation processes*?

It is necessary to operationalize several terms to answer these questions. An *asymmetry reversal* can be said to occur between two types, for a given area composed of several strata, when some strata exhibit a predominance of one type and other strata exhibit a predominance of the other type. The *magnitudes* of asymmetry reversals within an area can be measured in the following way. First, the numbers of strata having a predominance of one type vs. the other are summed. The *"normal" direction* of asymmetry within the area is then defined as that direction of asymmetry which occurs between the type that predominates in most strata and the type that is found less frequently in those strata. For each stratum S not having this direction of asymmetry, the magnitude of its asymmetry reversal A_s between the two types i and j can be defined conservatively as:

$$A_s = \frac{|N_{is} - N_{js}|}{N_{is} + N_{js}} \times 100\% \qquad (10)$$

where N_i and N_j are the numbers of items of the two types in the stratum. The difference in counts of the two types has been adjusted by their total numbers within the stratum in order to make the measure comparable between strata or study areas having different densities of the two types, and between artifact type pairs having different densities. Note, also, that within any given study area, multiple measures of the magnitude of asymmetry reversal within it may be defined, one for each stratum exhibiting a reversal.

The *commonness* of asymmetry reversals within a study area can be measured in several ways: by the percentage of depositional sets within the area that have type-pairs showing asymmetry reversals; by the percentage of all pairwise combinations of types that fall within the same depositional sets and that exhibit asymmetry reversals; or by the percentage of types within the area that exhibit asymmetry reversals with other types in their depositional set.

These percentages, however, must be calculated in reference to total numbers of sets, combinations, or types that have the *potential* to express asymmetry reversals. In this study, a pairwise combination of types within a depositional set was not considered to have the potential for expressing asymmetry reversals over strata if both types did not occur together in at least two strata. In other words, the conservative position was taken that asymmetries taken to the extreme circumstance where one type or the other of a pair is missing from all but one stratum (where both occur) should not be considered in the analysis, less these indicate dissociation of the types rather than misjudged asymmetry in coarrangement. Thus, of the 41 pairwise combinations of different types within the depositional sets defined in Table 17, only 36 have the potential for asymmetry reversals. The pairs, ivory-bead, ivory-vert, ivory-backbl, and bead-pierce, do not co-occur in two or more strata (Table 22). Of the 19 depositional sets, two (Sets 16, 18) do not have the potential to show asymmetry reversals because none of the pairwise combinations among their defining types do, and one (Set 15) does not because it is composed of a single type. Of the 23 types, only 19 have the potential for showing asymmetry reversals with other types. Ivory, bead, and pierce occur in sets where none of the pairwise combinations among types have the potential to exhibit asymmetry reversals, for lack of spatial co-occurrence in two or more strata, and scapula belongs to a set by itself.

Additional sets and pairwise combinations of types were excluded from analysis because they probably pertain to the fortuitous spatial overlap of deposition of different kinds of activity sets from different kinds of activities, rather than to the deposition of single activity sets. Only the latter circumstances reflect the internal organization of depositional sets; the former reflect external relationships among depositional sets. Thus, depositional sets 5, 6, and 7, and the type combinations exclusive to them, were dropped from analysis. This resulted in the characterization of 31 pairwise combinations, 14 depositional sets, and 19 types as having the potential to exhibit asymmetry reversals.

Three contrasts among sets of strata thought to represent different behavioral or depositional contexts were defined in order to study the correspondence of spatial variation in the direction of asymmetry of types and spatial variation in formation processes. These are 1) hearth strata (H1, H2, H3) vs. peripheral strata (the remainder); 2) peripheral strata northwest of the hearths (8, 9, 10, 11, 5, 6, 16) vs. peripheral strata southeast of the hearths (12, 13, 14); and 3) the hearth strata among themselves.

The first contrast among strata clearly involves differences in their behavioral use, and probably in the patterns of deposition within them. Different artifact types and depositional sets tended to have been deposited in the peripheral strata compared to the hearth strata (Tables 13, 17). Moreover, the hearth strata represent areas of the site where work space was limited yet activity was focused—circumstances encouraging the cleaning of use-areas and type-sorting processes, as evidenced by conjoined pieces studies (see p. 387). In contrast, the peripheral strata—particularly those outside the huts—were zones of less intense activity where work space was more available and cleaning of use-areas was probably less frequent, if it occurred at all. It can be expected that these probable differences in the activities and processes responsible for artifact deposition in the hearth and peripheral strata resulted in variation in the magnitude and/or direction of asymmetry of types among the strata.

Contrasting patterns of use and deposition among the peripheral strata northwest and southeast of the hearths are suggested in Table 26. The northwest strata have much higher frequencies of artifact types that are tools (e.g., burins, becs) or raw materials that are useful for making tools (e.g., antler, tibio). The southeast strata have higher frequencies of types, most of which represent bone refuse from broth making and bone grease making in the hearth strata (phal, meta, hfr). If it is considered that the northwest strata correspond to areas immediately outside a main entrance of the hut, whereas the southeast strata occur within the back of the hut or behind it, these differences in artifact type frequencies become interpretable. The deposition of tools and raw materials around the entrance of the hut suggests the fabrication or maintenance of tools and goods in the daylight hours of warmer periods, outside, where light was better—a pattern similar to that found among the !Kung Bushmen (Yellen, 1974). The debris left from these activities, and perhaps others in the area, possibly represent primary refuse. In contrast, in the rear of the hut's interior and behind it, secondary refuse deposition is indicated by the presence, there, of debris that originated in the hearth strata during broth and bone grease making activities. Presumably, this material was swept to the rear of the huts or dumped behind them while cleaning the central hearth areas—a supposition supported by the conjoined pieces studies. This translocation of refuse, of course, would have allowed various sorting processes to have occurred and would have altered the pattern of asymmetry among artifact types. Thus, again, spatial variation in the magnitude and/or direction of asymmetry among types is expectable for two different sets of strata.

Contrasting patterns of use and deposition are also likely among the three hearth strata, particularly H2 and H3 vs. H1. It would appear that hearth 1 was used more for cooking (particularly broth making and bone grease making)

Table 13.26

Proportions of Artifact Types within Peripheral Strata Southeast vs. Northwest of the Hearths

Tool Type	*Counts in Northwest Strata (8,9,10,11,5,6,16)*	*Counts in Southeast Strata (12,13,14)*	*Ratio of Counts, Southeast:Northwest Strata*
*Less Hearth-Oriented Types**			
pierce	2	0	0.
microp	5	1	.2
bead	1	0	0.
antler	6	1	.16
tibio	10	7	.70
scapula	2	3	**1.50
vert	5	0	0.
maxill	3	3	1.00
More Hearth-Oriented Types			
core	7	3	.42
burin	22	8	.36
burinsp	9	1	.11
bec	6	1	.16
notch	4	0	0.
backbl	2	0	0.
utblade	15	3	.20
phal	8	9	**1.12
meta	6	22	**3.70
rib	20	16	.80
hfr	15	28	**1.80
mandib	6	1	.16
scrapa	1	2	**2.00
scrapbc	5	1	.20
ivory	2	0	0.

*Defined in Table 13.

**Indicates types having anomalously higher frequencies in strata southeast of hearths.

while hearths 2 and 3 were used more to supply heat to surrounding work areas (where tools were made and maintained and goods were fabricated) and sleeping areas. This difference is suggested in several ways. 1) Hearth strata 2 and 3 exhibit much higher frequencies of cores, burins, burin spalls, becs, scrapers (type bc), backed bladelets, and unbacked blades, than hearth stratum 1, whereas hearth stratum 1 has higher frequencies of metapods (from bone grease making) than strata 2 and 3. 2) Large blocks of stone useful for sitting and surrounded by concentrations of tools, indicating work areas, occur in hearth strata 2 and 3, but not 1. 3) The basin of hearth 1 is filled primarily with carbon deposits, indicating the major source of fire in the hut, whereas the basins of hearths 2 and 3 are filled more with fire-cracked rocks, indicating indirect heating (Leroi-Gourhan & Brézillon, 1966, p. 367). 4) Surrounding the hearths are debris-free areas which are 20-30 cm in diameter and in which there possibly stood racks that supported skins for stone boiling, broth making, and bone grease making. These are more frequent around hearth 1 (5 places) than hearth 2 (3 places) or hearth 3 (2 places) (ibid, p. 367).

Although it is clear that hearths 2 and 3 differ in their function from hearth 1, the difference appears to be largely one of degree rather than kind. Cooking and fabrication debris occur around all three hearths (Table 13), as do the debris-free areas that were possibly used in stone boiling. Moreover, the difference may pertain more to the frequency of tool manufacture and fabrication activities than to cooking activities. Some classes of debris from broth and bone grease making (phal, hfr) occur in more equal frequencies among all the hearths.

These differences among the hearths in their use, even if only quantitative, suggest that different patterns of deposition may characterize the strata in which they occur. The frequency with which the work areas that surround the hearths were cleaned, in particular, may have varied among them. These differences in formation processes, again, could have produced different magnitudes and directions of asymmetry among the artifact types in the different strata.

The three contrasts—among hearth and peripheral strata, northwest and southeast peripheral strata, and among hearth strata—allow one to examine whether asymmetry reversals over space correspond with spatial variation in formation processes. To show a correspondence for a given group of contrasting strata, it is necessary to show only that all or most strata having the "normal" direction of asymmetry fall in one contrast set (e.g., northwest peripheral strata) and the remaining strata having the reversed direction fall in the other contrast set (e.g., southeast peripheral strata). As the percentage of type-pairs that exhibit asymmetry reversals and show this correspondence increases for the group of contrasting strata, our confidence in a systematic relationship between asymmetry reversals and spatial variation in formation processes increases.

Having operationalized the three questions posed above, it now is possible to determine their answers with the Pincevent data.

1) Magnitude of asymmetry reversals. The average magnitude of asymmetry reversals among artifact types in the same depositional set, over all strata within the site, is significant: 4.32% ± 4.68%. Considering only the strata within the hearth-to-hearth contrast, where formation processes are known to have varied among hearths, the average magnitude of asymmetry reversals is more substantial: 10.96% ± 7.39%. Similarly, considering only the strata within the northwest-to-southeast peripheral strata contrast, again where spatial variation in formation processes is more certain, the average is high: 8.53% ± 5.25%.

2) Commonness of asymmetry reversals. Asymmetry reversals are very common in the Pincevent data. First, considering asymmetry reversals of any magnitude, it was found that of the 14 depositional sets having the potential for asymmetry reversals, 9 (64.3%) were composed of types, at least one of which exhibited asymmetry reversals with other types in its set. Of the 31 pairwise combinations of types having the potential for asymmetry reversals and occurring within the same depositional set, 20 (64.5%) involved asymmetry reversals over the strata in which the types occurred. Of the 19 types having the potential to show asymmetry reversals with other types in their depositional set, 17 (89.47%) exhibited such reversals.[4]

Considering only asymmetry reversals greater than 4% in magnitude, it was found that of 14 depositional sets having the potential for asymmetry reversals, 6 (42.9%) were composed of types, at least one of which exhibited asymmetry reversals with other types in its set. Of the 31 pairwise combinations of types having the potential for asymmetry reversals, 11 (35.5%) involved asymmetry reversals. Of the 19 types having the potential to show asymmetry reversals with other types in their depositional set, 14 (73.6%) exhibited reversals.[5]

Thus, asymmetry reversals among types within the depositional sets of Pincevent are quite common, and of significant magnitude. This is true even without counting those extreme cases of asymmetry, where one type is missing from the stratum in which another of the same depositional set occurs.

Of course, it must also be remembered that the statistics just discussed assume a particular mathematical method for defining which types comprise depositional sets. The types that comprise sets and the statistics that were calculated would differ somewhat if a different similarity coefficient or different distance thresholds for defining sets had been used. In particular, using AVDISTLP1 allowed the definition of sets having asymmetry reversals among types. At the same time, this coefficient seems more concordant with the relevant structure of the Pincevent data than do other coefficients, which gives support to at least the overall pattern of the statistics, if not their exact values.

3) Relation of asymmetry reversals to formation processes. Correspondences between spatial variation in the direction of asymmetry among types and spatial variation in formation processes were found to differ in strength for the three contrast studies. In the contrast between northwest and southeast peripheral strata, 2 pairs of types were found to have asymmetry reversals among the strata of interest. For both, *all* strata having the normal direction of asymmetry fell in one contrast set (either the northwest or southeast strata) and *all* strata having the reverse direction of asymmetry fell in the other. In the contrast between hearth and peripheral strata, 16 pairs of types were found to have asymmetry reversals among the strata of interest. For 3 of these type-pairs, all strata having the normal direction of asymmetry and all strata having the reverse direction of asymmetry fell into opposite contrast sets (either hearth or peripheral strata). For an additional 4 type-pairs, most strata having the normal direction of asymmetry and most having the reverse direction fell into opposite contrast sets. Thus, in the hearth-to-peripheral strata contrast, a total of 7 of 16 type-pairs (43.8%) exhibited full or partial correspondence between spatial variation in their direction of asymmetry and spatial variation in formation processes. In the hearth-to-hearth contrast, 11 pairs of types were found to express asymmetry reversals among the strata of interest. Only 3 of the 11 pairs (27.3%) exhibited the expected pattern, where reversals in the direction of asymmetry should distinguish hearth 1 from hearths 2 and 3. However, 6 of the 11 pairs (54.5%) did exhibit a pattern in which reversals in the direction of asymmetry distinguished hearth 3 from hearths 2 and 1. This stronger pattern, though unexpected, is nevertheless significant. It defines a more systematic variation in the direction of asymmetry among type-pairs over space. It also suggests that the formation processes distinguishing the three hearths from each other are not well enough understood, from the perspective of either Leroi-Gourhan and Brézillon's or Binford's interpretation of site use.

Thus, although there is some evidence in the Pincevent data for systematic relationships between spatial variation in the direction of asymmetry among artifact types in the same depositional set and spatial variation in formation processes, the evidence is not uniformly strong or conclusive. I would suggest that this probably relates more to oversimplification of the expectations posed compared to the complexity of the formation processes structuring the data, than to the validity of the general premise. The relationship between asymmetry and formation process should be investigated in other sites, where greater knowledge of their processes of formation is available through data of the kind suggested by Schiffer (1983).

In sum, the Pincevent data suggest that within a site, the magnitude and direction of asymmetry among artifact types within depositional sets can vary frequently, and to a great degree, from deposit to deposit. It is apparent that these forms of spatial variation—and the monothetic-polythetic dimension of organization that can be related to them—must be considered when choosing a similarity coefficient for defining site-wide depositional sets.

CONCLUSION

Scientific progress is marked not only by the development of models and theory allowing accurate prediction, but also an increase in logical congruence between techniques of analysis and the relevant structure of the data to be investigated. The latter can be achieved only by continuously developing and testing new methods, and by constructing models of relevant data structures that are suggested by current theory and empirical fact. It is hoped that the techniques and models for intrasite spatial analysis discussed in this chapter, as well as the example given, provide food for further thought and development.

NOTES

1. See Carr, chapter 2 for a general definition of relevant data structure, relevant relational data structure, and relevant subset data structure. In this context, a relevant data structure encompasses variables and observations and forms of relationships among them that are pertinent to the researcher's interest in past behavioral phenomena (e.g., tool kits, storage sets, activities) or natural environmental phenomena (e.g., geomorphological activity).

2. The changes that occur in relationships among artifact types as a result of formation processes can be called "biases" only from the perspective of their organization in the behavioral domain and our preconceptions that artifact organization in the archaeological domain should mirror that in the behavioral, as at Pompeii (Binford, 1981a).

3. The degree of *inconsistency* allowed between pairwise relationships among types when smoothing them should not be confused with the *levels of similarity* used in defining groups of types in polythetic agglomerative clustering routines or matrix ordering procedures after "smoothing" operations have been achieved.

4. The 17 types are burin, burinsp, backbl, utblade, bec, phal, meta, hfr, rib, tibio, core, microp, scrapa, notch, mandib, maxill, and vert.

5. The 14 types are burin, burinsp, backbl, utblade, bec, phal, hfr, rib, meta, microp, scrapa, core, mandib, vert.

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APPENDIX A: COMPUTER PROGRAMS FOR CALCULATING THE SIMILARITY COEFFICIENTS, AVDISTGM, AVDISTLP1, AND AVDISTGP

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C*******************************************************************************
C
C                             PROGRAM POLYTHETIC1
C
C*******************************************************************************
C
C
C THIS PROGRAM CAN BE USED TO CALCULATE A MATRIX OF AVDISTM SIMILARITY
C COEFFICIENTS AND A MATRIX OF AVDISTGP SIMILARITY COEFFICIENTS AS
C DEFINED IN THE TEXT OF THIS PAPER.  THE TWO KINDS OF COEFFICIENTS DEFINE
C THE DEGREE OF SPATIAL COARRANGEMENT OF PAIRS OF ARTIFACT CLASSES ASSUMING
C DIFFERENT STANDARDS OF PERFECT COARRANGEMENT.  AVDISTM, A MONOTHETIC AVERAGE
C NEAREST NEIGHBOR DISTANCE BETWEEN ITEMS OF DIFFERENT ARTIFACT CLASSES,
C ASSUMES A MODEL 1 FORM OF COARRANGEMENT.  AVDISTGP, A GLOBALLY POLYTHETIC
C AVERAGE NEAREST NEIGHBOR DISTANCE BETWEEN ITEMS OF DIFFERENT ARTIFACT
C CLASSES, ASSUMES A MODEL 5 FORM OF COARRANGEMENT.
C
C IN SKETCH, THE PROGRAM INVOLVES SIX BASIC STEPS.  (1) IT READS THE X-Y
C COORDINATES OF ALL ITEMS IN EACH ARTIFACT CLASS TO BE USED IN CALCULATING
C THE AVDISTM AND AVDISTGP COEFFICIENTS.  (2) IT WRITES OUT VARIOUS INPUT
C VALUES AND STATISTICS THAT ALLOW THE USER TO CHECK WHETHER THE
C DATA HAVE BEEN READ CORRECTLY.  (3) IT CALCULATES THE AVERAGE NEAREST
C NEIGHBOR DISTANCE FROM ITEMS OF ONE ARTIFACT CLASS TO ITEMS OF ANOTHER, AND
C VICE VERSA, DEFINING AN ASYMMETRIC MATRIX OF AVDIST1 AND AVDIST2 COEF-
C FICIENTS, AS DESCRIBED IN THE TEXT.  (4) FOR EACH PAIR OF A BASE ARTIFACT
C CLASS AND A REFERENCE ARTIFACT CLASS TO WHICH A GIVEN AVDIST1 OR AVDIST2
C COEFFICIENT PERTAINS, THE PROGRAM OUTPUTS A LISTING OF ALL NEAREST NEIGHBOR
C DISTANCES FROM THE ITEMS OF THE BASE CLASS TO ITEMS OF THE REFERENCE CLASS
C THAT ARE USED IN CALCULATING THE AVDIST1 OR AVDIST2 COEFFICIENT.  THIS
C INFORMATION CAN BE USED TO GENERATE A HISTOGRAM OF NEAREST NEIGHBOR DISTANCES
C FOR EACH BASE CLASS/REFERENCE CLASS PAIR.  HISTOGRAMS OF THIS KIND CAN BE
C USED TO CHECK THE DATA FOR OUTLYING ITEMS OR FOR MULTIMODALITY IN DISTANCE
C RELATIONSHIPS, ALLOWING ONE TO ASSESS THE MEANINGFULNESS OF COMPUTING AN
C AVERAGE DISTANCE STATISTIC, AVDIST1 OR AVDIST2.  (5) THE PROGRAM CALCULATES
C A SYMMETRIC MATRIX OF AVDISTGP COEFFICIENTS FOR ALL ARTIFACT CLASS PAIRS AND
C A SYMMETRIC MATRIX OF AVDISTM COEFFICIENTS FOR ALL ARTIFACT CLASS PAIRS FROM
C THE ASYMMETRIC MATRIX OF AVDIST1 AND AVDIST2 COEFFICIENTS.  (6) THE PROGRAM
C OUTPUTS THE MATRIX OF AVDIST1 AND AVDIST2 COEFFICIENTS, THE MATRIX OF
C AVDISTGP COEFFICIENTS, AND THE MATRIX OF AVDISTM COEFFICIENTS, IN THAT ORDER.
C THE ASYMMETRIC MATRIX OF AVDIST1 AND AVDIST2 COEFFICIENTS GIVES THE
C RESEARCHER ONE MEANS FOR INVESTIGATING THE DIRECTION AND DEGREE OF
C ASYMMETRY BETWEEN VARIOUS PAIRS OF ARTIFACT CLASSES WITHIN THE STUDY AREA.
C
C SYSTEM UNITS AND FILES LINKED TO THEM, AS REQUIRED BY THE PROGRAM:
C
C UNIT 1.  THIS UNIT SHOULD BE LINKED TO A FILE CONTAINING A 1 COLUMN X N ROW
C MATRIX OF THE NUMBER OF ARTIFACT OBSERVATIONS IN EACH ARTIFACT CLASS, IN
C THE FORMAT (1X,I4).  THE NUMBER OF ROWS, N, SHOULD EQUAL THE NUMBER OF
C ARTIFACT CLASSES.
C
C UNIT 2.  THIS UNIT SHOULD BE LINKED TO A FILE CONTAINING A 2 COLUMN X N ROW
C MATRIX OF THE X-Y SPATIAL COORDINATES OF THE ITEMS OF ALL ARTIFACT CLASSES,
C IN THE FORMAT (F7.3,1X,F7.3).  THE NUMBER OF ROWS, N, SHOULD EQUAL THE
C NUMBER OF ALL ITEMS OF ALL ARTIFACT CLASSES.  THE X-Y COORDINATE PAIRS
C SHOULD BE ARRANGED SEQUENTIALLY BY THE ARTIFACT CLASS OF THE ITEMS
C THEY REPRESENT, WITH THE ORDER OF CLASSES BEING THE SAME AS THAT IN
C THE FILE LINKED TO UNIT 1.  FOR CONVENIENCE, THE USER MAY WISH TO KEEP
C THE COORDINATE PAIRS FOR EACH ARTIFACT CLASS IN A SEPARATE FILE AND
C THEN STACK THE FILES INTO ONE MASTER FILE OF THE REQUIRED FORMAT WHEN
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C USING THE PROGRAM.
C UNIT 6.  THIS UNIT SHOULD BE LINKED TO A FILE OR DEVICE TO RECEIVE OUTPUT
C MONITORING THE PROGRESS OF THE PROGRAM AND WHETHER THE DATA ATTACHED TO
C UNITS 1 AND 2 HAVE BEEN READ CORRECTLY.  THE OUTPUT ROUTED TO THIS UNIT
C INCLUDES:  (A) A TOTAL OF THE NUMBER OF ARTIFACT CLASSES, (B) THE SEQUENTIAL
C ORDER NUMBER OF THOSE CLASSES OF ARTIFACTS THAT HAVE BEEN READ SUCCESSFULLY,
C AND (C) THE LAST X-Y COORDINATE PAIR OF EACH ARTIFACT CLASS THAT HAS BEEN
C READ SUCCESSFULLY.
C
C UNIT 3.  THIS UNIT SHOULD BE LINKED TO A FILE TO RECEIVE OUTPUT USEFUL IN
C GENERATING HISTOGRAMS OF NEAREST NEIGHBOR DISTANCES FOR EACH BASE CLASS/
C REFERENCE CLASS PAIR OF ARTIFACT CLASSES.  THE OUTPUT CONSISTS OF A SERIES
C OF MATRICES FOLLOWED BY AND SEPARATED BY THE WORD, "END," ONE MATRIX FOR
C EACH BASE CLASS.  EACH MATRIX HAS AS MANY ROWS AS THERE ARE ITEMS IN THE BASE
C CLASS (ONE ROW FOR EACH ITEM IN THE BASE CLASS) AND AS MANY COLUMNS AS THERE
C ARE ARTIFACT CLASSES (ONE COLUMN FOR EACH ARTIFACT CLASS, IN THE READ ORDER).
C THE ENTRIES DOWN ANY GIVEN COLUMN SPECIFY THE NEAREST NEIGHBOR DISTANCES
C FROM THE ITEMS OF THE BASE CLASS TO WHICH THE MATRIX PERTAINS TO ITEMS OF THE
C ARTIFACT CLASS (REFERENCE CLASS) ASSOCIATED WITH THAT COLUMN.  THE REFERENCE
C CLASS CAN BE THE BASE CLASS, ITSELF.  THE FORMAT OF ANY GIVEN ROW IS
C N(1X,F7.3), WHERE N IS THE NUMBER OF ARTIFACT CLASSES.
C
C UNIT 4.  THIS UNIT SHOULD BE LINKED TO A FILE TO RECEIVE THE OUTPUT MATRICES
C OF AVDIST1/AVDIST2 COEFFICIENTS, AVDISTGP COEFFICIENTS, AND AVDISTM COEF-
C FICIENTS, IN THAT ORDER.  THE THREE MATRICES ARE N X N IN DIMENSION, WHERE
C N IS THE NUMBER OF ARTIFACT CLASSES.  TO ALLOW THEM TO BE DISPLAYED ON AN
C 80-COLUMN PRINTER, EACH MATRIX GREATER THAN 10 COLUMNS X 10 ROWS IS BROKEN
C INTO TWO OR THREE SUBMATRICES OF 10 OR LESS COLUMNS X N ROWS, WHERE N IS THE
C NUMBER OF ARTIFACT CLASSES.  THE SUBMATRICES ARE OUTPUTTED SEQUENTIALLY,
C SEPARATED BY BLANK ROWS.  THE ELEMENTS IN EACH ROW OF A MATRIX OR SUBMATRIX
C HAVE THE FORMAT M(1X,F7.3), WHERE M IS THE NUMBER OF ELEMENTS PER ROW (10 OR
C LESS).  EACH MATRIX OR SUBMATRIX IS PRECEDED BY 5 BLANK ROWS.
C
C DEFINITION OF VARIABLES, ARRAYS, AND LIMITATIONS OF THE PROGRAM:
C
C NPOINT(26).  THE ARRAY OF NUMBERS OF ITEMS IN EACH ARTIFACT CLASS, FOR UP TO
C      26 CLASSES.  THE CONTENTS OF THIS ARRAY ARE READ FROM A FILE LINKED TO
C      UNIT 1.
C NCLASS.  THE NUMBER OF ARTIFACT CLASSES IN THE DATA SET.
C ART(2,381,26).  THE MATRIX OF 2 (X AND Y) SPATIAL COORDINATES FOR EACH OF
C      UP TO 381 ITEMS IN UP TO 26 ARTIFACT CLASSES.  THE CONTENTS OF THIS
C      MATRIX ARE READ FROM A FILE LINKED TO UNIT 2.
C AVDIST(26,26).  THE ASYMMETRIC MATRIX OF AVDIST1 AND AVDIST2 COEFFICIENTS FOR
C      UP TO 26 ARTIFACT CLASSES.  THE CONTENTS OF THIS MATRIX ARE OUTPUTTED TO
C      A FILE LINKED WITH UNIT 4.
C POLYD(26,26).  THE SYMMETRIC MATRIX OF AVDISTGM COEFFICIENTS FOR UP TO 26
C      ARTIFACT CLASSES.  THE CONTENTS OF THIS MATRIX ARE OUTPUTTED TO A FILE
C      LINKED WITH UNIT 4.
C XMONOD(26,26).  THE SYMMETRIC MATRIX OF AVDISTM COEFFICIENTS FOR UP TO 26
C      ARTIFACT CLASSES.  THE CONTENTS OF THIS MATRIX ARE OUTPUTTED TO A FILE
C      LINKED WITH UNIT 4.
C SUM(26,26).  AN ASYMMETRIC MATRIX OF SUMS OF NEAREST NEIGHBOR DISTANCES USED
C      IN CALCULATING THE MATRIX AVDIST.
C DST.  THE DISTANCE FROM AN ITEM OF A BASE CLASS TO AN ITEM OF A REFERENCE
C      CLASS.  THE TWO ITEMS ARE NOT NECESSARILY NEAREST NEIGHBORS.
C DIST(381,26).  A MATRIX OF NEAREST NEIGHBOR DISTANCES FROM THE ITEMS OF A
C      SPECIFIED BASE CLASS (WITH UP TO 381 ITEMS) TO ITEMS OF REFERENCE
C      CLASSES.  THE PROGRAM CALCULATES AS MANY DIST MATRICES AS THERE ARE
C      ARTIFACT CLASSES (I.E., BASE CLASSES).  THE CONTENTS OF THESE MATRICES
C      ARE OUTPUTTED TO A FILE LINKED WITH UNIT 3.
C IT IS POSSIBLE TO INCREASE THE PROGRAM'S LIMITS ON THE NUMBER OF ITEMS PER
C ARTIFACT CLASS TO 9999 AND THE NUMBER OF ARTIFACT CLASSES UP TO 30 BY
C ADJUSTING THE LIMITS SET IN THE DIMENSION STATEMENT (LINES 10, 20).  ANY
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C FURTHER INCREASE IN THE NUMBER OF ITEMS PER CLASS OR NUMBER OF ARTIFACT
C CLASSES REQUIRES MORE BASIC PROGRAM MODIFICATION IN THE INPUT AND OUTPUT
C STATEMENTS (LINES 80, 110, 710-1170).
C
C IT IS ASSUMED THAT THE COORDINATES OF ITEMS RANGE BETWEEN -99.999 AND
C 999.999, THAT THE MAXIMUM DISTANCE SEPARATING ANY PAIR OF ITEMS IS 99999.,
C AND THAT THE MAXIMUM AVERAGE DISTANCE (AVDIST1, AVDIST2, AVDISTGP, OR
C AVDISTM) FROM ITEMS OF ONE CLASS TO ITEMS OF ANOTHER IS 999.999.
C
C THIS PROGRAM WAS WRITTEN AND IS SUPPORTED BY:
C
C                          CHRISTOPHER CARR
C                          DEPARTMENT OF ANTHROPOLOGY AND
C                          INSTITUTE FOR QUANTITATIVE ARCHAEOLOGY
C                          UNIVERSITY OF ARKANSAS
C                          FAYETTEVILLE, AR 72701
C
C
C*******************************************************************************
C
C
      DIMENSION ART(2,381,26),NPOINT(26),SUM(26,26),DIST(381,26)        INT00010
     1,AVDIST(26,26),POLYD(26,26),XMONOD(26,26)                         INT00020
C   READ IN ARRAY OF NUMBER OF OBSERVATIONS IN EACH ARTIFACT CLASS AND  INT00030
C CALCULATE NUMBER OF ARTIFACT CLASSES                                  INT00040
      KOUNT=0                                                           INT00050
      DO 10 I=1,100                                                     INT00060
      READ(1,101,END=500)NPOINT(I)                                      INT00070
      KOUNT=KOUNT+1                                                     INT00080
      WRITE(6,101)NPOINT(I)                                             INT00090
   10 CONTINUE                                                          INT00100
  500 NCLASS=KOUNT                                                      INT00110
C READ IN ARRAY OF OBSERVED LOCATIONS OF ITEMS OF EACH CLASS            INT00120
      DO 11 KLASS=1,NCLASS                                              INT00130
      NPT=NPOINT(KLASS)                                                 INT00140
      DO 9 KPOINT=1,NPT                                                 INT00150
      READ(2,103)(ART(KCOOR,KPOINT,KLASS),KCOOR=1,2)                    INT00160
    9 CONTINUE                                                          INT00170
      WRITE(6,102)KLASS                                                 INT00180
      WRITE(6,107)(ART(KCOOR,KPOINT,KLASS),KCOOR=1,2)                   INT00190
   11 CONTINUE                                                          INT00200
C INITIATE DOS FOR OPERATING ON CLASS PAIRS OR A CLASS WITH ITSELF      INT00210
      DO 12 ICLASS=1,NCLASS                                             INT00220
      NPTB=NPOINT(ICLASS)                                               INT00230
      DO 13 JCLASS=1,NCLASS                                             INT00240
      SUM(JCLASS,ICLASS)=0.                                             INT00250
      NPTR=NPOINT(JCLASS)                                               INT00260
C INITIATE SEARCH FOR NEAREST NEIGHBOR OF SAME OR DIFFERENT CLASS       INT00270
      DO 14 KPNTB=1,NPTB                                                INT00280
      DMIN=99999.                                                       INT00290
      DO 15 KPNTR=1,NPTR                                                INT00300
      DST=SQRT((ART(1,KPNTB,ICLASS)-ART(1,KPNTR,JCLASS))**2+            INT00310
     1(ART(2,KPNTB,ICLASS)-ART(2,KPNTR,JCLASS))**2)                     INT00320
      IF(DST.LT.DMIN)DMIN=DST                                           INT00330
   15 CONTINUE                                                          INT00340
      DIST(KPNTB,JCLASS)=DMIN                                           INT00350
   14 CONTINUE                                                          INT00360
C FIND AVDIST FOR ITEMS OF 1 BASE CLASS TO ITEMS OF 1 REFERENCE CLASS   INT00370
      DO 27 KPOINT=1,NPTB                                               INT00380
      SUM(JCLASS,ICLASS)=SUM(JCLASS,ICLASS)+DIST(KPOINT,JCLASS)         INT00390
   27 CONTINUE                                                          INT00400
      AVDIST(JCLASS,ICLASS)=SUM(JCLASS,ICLASS)/NPOINT(ICLASS)           INT00410
   13 CONTINUE                                                          INT00420
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C WRITE NEAREST NEIGHBOR DISTANCES FOR ALL ITEMS OF ONE BASE CLASS TO   INT00430
C ITEMS OF MULTIPLE REFERENCE CLASSES                                    INT00440
      DO 50 KPNTB=1,NPTB                                                INT00450
      WRITE(3,104)(DIST(KPNTB,JCLASS),JCLASS=1,NCLASS)                  INT00460
   50 CONTINUE                                                          INT00470
      WRITE(3,108)                                                      INT00480
   12 CONTINUE                                                          INT00490
C FIND MINIMUM OF AVDIST1 AND AVDIST2, DEFINING AVDISTGP (POLYD)        INT00500
      DO 19 ICLASS=1,NCLASS                                             INT00510
      DO 20 JCLASS=1,NCLASS                                             INT00520
      POLYD(JCLASS,ICLASS)=AMIN1(AVDIST(JCLASS,ICLASS),AVDIST(ICLASS,   INT00530
     1JCLASS))                                                          INT00540
   20 CONTINUE                                                          INT00550
   19 CONTINUE                                                          INT00560
C CALCULATE AVDISTM (XMONOD)                                            INT00570
      DO 23 ICLASS=1,NCLASS                                             INT00580
      DO 24 JCLASS=1,NCLASS                                             INT00590
      XMONOD(JCLASS,ICLASS)=(SUM(JCLASS,ICLASS)+SUM(ICLASS,JCLASS))/    INT00600
     1(NPOINT(JCLASS)+NPOINT(ICLASS))                                   INT00610
   24 CONTINUE                                                          INT00620
   23 CONTINUE                                                          INT00630
C WRITE MATRICES OF AVDIST, POLYD, AND XMONOD VALUES TO UNIT4           INT00640
      WRITE(4,105)                                                      INT00650
      IF(NCLASS .LE. 10) GO TO 56                                       INT00660
      IF(NCLASS .LE. 20) GO TO 57                                       INT00670
      IF(NCLASS .LE. 30) GO TO 58                                       INT00680
   56 DO 30 ICLASS=1,NCLASS                                             INT00690
      WRITE(4,106)(AVDIST(JCLASS,ICLASS),JCLASS=1,NCLASS)               INT00700
   30 CONTINUE                                                          INT00710
      GO TO 91                                                          INT00720
   57 DO 31 ICLASS=1,NCLASS                                             INT00730
      WRITE(4,106)(AVDIST(JCLASS,ICLASS),JCLASS=1,10)                   INT00740
   31 CONTINUE                                                          INT00750
      WRITE(4,105)                                                      INT00760
      DO 32 ICLASS=1,NCLASS                                             INT00770
      WRITE(4,106)(AVDIST(JCLASS,ICLASS),JCLASS=11,NCLASS)              INT00780
   32 CONTINUE                                                          INT00790
      GO TO 91                                                          INT00800
   58 DO 33 ICLASS=1,NCLASS                                             INT00810
      WRITE(4,106)(AVDIST(JCLASS,ICLASS),JCLASS=1,10)                   INT00820
   33 CONTINUE                                                          INT00830
      WRITE(4,105)                                                      INT00840
      DO 34 ICLASS=1,NCLASS                                             INT00850
      WRITE(4,106)(AVDIST(JCLASS,ICLASS),JCLASS=11,20)                  INT00860
   34 CONTINUE                                                          INT00870
      WRITE(4,105)                                                      INT00880
      DO 35 ICLASS=1,NCLASS                                             INT00890
      WRITE(4,106)(AVDIST(JCLASS,ICLASS),JCLASS=21,NCLASS)              INT00900
   35 CONTINUE                                                          INT00910
   91 CONTINUE                                                          INT00920
      WRITE(4,105)                                                      INT00930
      IF(NCLASS .LE. 10) GO TO 66                                       INT00940
      IF(NCLASS .LE. 20) GO TO 67                                       INT00950
      IF(NCLASS .LE. 30) GO TO 68                                       INT00960
   66 DO 36 ICLASS=1,NCLASS                                             INT00970
      WRITE(4,106)(POLYD(JCLASS,ICLASS),JCLASS=1,NCLASS)                INT00980
   36 CONTINUE                                                          INT00990
      GO TO 92                                                          INT01000
   67 DO 37 ICLASS=1,NCLASS                                             INT01010
      WRITE(4,106)(POLYD(JCLASS,ICLASS),JCLASS=1,10)                    INT01020
   37 CONTINUE                                                          INT01030
      WRITE(4,105)                                                      INT01040
      DO 38 ICLASS=1,NCLASS                                             INT01050
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      WRITE(4,106)(POLYD(JCLASS,ICLASS),JCLASS=11,NCLASS)               INT01060
   38 CONTINUE                                                          INT01070
      GO TO 92                                                          INT01080
   68 DO 39 ICLASS=1,NCLASS                                             INT01090
      WRITE(4,106)(POLYD(JCLASS,ICLASS),JCLASS=1,10)                    INT01100
   39 CONTINUE                                                          INT01110
      WRITE(4,105)                                                      INT01120
      DO 40 ICLASS=1,NCLASS                                             INT01130
      WRITE(4,106)(POLYD(JCLASS,ICLASS),JCLASS=11,20)                   INT01140
   40 CONTINUE                                                          INT01150
      WRITE(4,105)                                                      INT01160
      DO 41 ICLASS=1,NCLASS                                             INT01170
      WRITE(4,106)(POLYD(JCLASS,ICLASS),JCLASS=21,NCLASS)               INT01180
   41 CONTINUE                                                          INT01190
   92 CONTINUE                                                          INT01200
      WRITE(4,105)                                                      INT01210
      IF(NCLASS .LE. 10) GO TO 76                                       INT01220
      IF(NCLASS .LE. 20) GO TO 77                                       INT01230
      IF(NCLASS .LE. 30) GO TO 78                                       INT01240
   76 DO 42 ICLASS=1,NCLASS                                             INT01250
      WRITE(4,106)(XMONOD(JCLASS,ICLASS),JCLASS=1,NCLASS)               INT01260
   42 CONTINUE                                                          INT01270
      GO TO 88                                                          INT01280
   77 DO 43 ICLASS=1,NCLASS                                             INT01290
      WRITE(4,106)(XMONOD(JCLASS,ICLASS),JCLASS=1,10)                   INT01300
   43 CONTINUE                                                          INT01310
      WRITE(4,105)                                                      INT01320
      DO 44 ICLASS=1,NCLASS                                             INT01330
      WRITE(4,106)(XMONOD(JCLASS,ICLASS),JCLASS=11,NCLASS)              INT01340
   44 CONTINUE                                                          INT01350
      GO TO 88                                                          INT01360
   78 DO 45 ICLASS=1,NCLASS                                             INT01370
      WRITE(4,106)(XMONOD(JCLASS,ICLASS),JCLASS=1,10)                   INT01380
   45 CONTINUE                                                          INT01390
      WRITE(4,105)                                                      INT01400
      DO 46 ICLASS=1,NCLASS                                             INT01410
      WRITE(4,106)(XMONOD(JCLASS,ICLASS),JCLASS=11,20)                  INT01420
   46 CONTINUE                                                          INT01430
      WRITE(4,105)                                                      INT01440
      DO 47 ICLASS=1,NCLASS                                             INT01450
      WRITE(4,106)(XMONOD(JCLASS,ICLASS),JCLASS=21,NCLASS)              INT01460
   47 CONTINUE                                                          INT01470
  101 FORMAT(1X,I4)                                                     INT01480
  102 FORMAT(1X,I2)                                                     INT01490
  103 FORMAT(F7.3,1X,F7.3)                                              INT01500
  104 FORMAT(100(1X,F7.3))                                              INT01510
  105 FORMAT(/////)                                                     INT01520
  106 FORMAT(10(1X,F7.3))                                               INT01530
  107 FORMAT(1X,F7.3,1X,F7.3)                                           INT01540
  108 FORMAT(1X,'END')                                                  INT01550
   88 STOP                                                              INT01560
      END                                                               INT01570

C***********************************************************************
C
C
C                            PROGRAM POLYTHETIC2
C
C
C***********************************************************************
C
C
C THIS PROGRAM CAN BE USED TO CALCULATE A MATRIX OF AVDISTLP1 SIMILARITY
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C COEFFICIENTS, DEFINING THE DEGREE OF SPATIAL COARRANGEMENT OF PAIRS OF
C ARTIFACT CLASSES.  AS DISCUSSED IN THE TEXT OF THIS PAPER, AVDISTLP1
C IS A LOCALLY POLYTHETIC AVERAGE NEAREST NEIGHBOR DISTANCE BETWEEN
C ITEMS OF TWO DIFFERENT ARTIFACT CLASSES.  THE COEFFICIENT ASSUMES A
C MODEL 4 FORM OF PERFECT COARRANGEMENT.  IN THIS CASE, THE MAGNITUDE,
C AND DIRECTION OF ASYMMETRY BETWEEN ANY GIVEN PAIR OF ARTIFACT CLASSES
C CAN VARY FROM ARTIFACT CLUSTER TO ARTIFACT CLUSTER (OR ANY OTHER AREAL
C STRATUM HOMOGENEOUS IN THE FORMATION PROCESSES AFFECTING ASYMMETRY).
C HOWEVER, ASYMMETRY CAN NOT BE TAKEN TO THE EXTREME WHERE ONE ARTIFACT
C CLASS IS ABSENT FROM STRATA CONTAINING THE OTHER, AND VICE VERSA.
C
C IN CALCULATING AVDISTLP1 COEFFICIENTS, THIS PROGRAM REQUIRES THAT THE
C AREAL STRATUM AFFILIATION OF EACH ARTIFACT, AS WELL AS ITS X AND Y
C SPATIAL COORDINATES, BE KNOWN.  AREAL STRATA NEED NOT BE CLUSTERS OF
C ARTIFACTS THAT ARE SPATIALLY DISCRETE AND HAVE EASILY DEFINABLE
C BORDERS.  THEY CAN BE SOMEWHAT OVERLAPPING CLUSTERS, THE BOUNDARIES
C BETWEEN WHICH HAVE BEEN ONLY APPROXIMATED, OR MORE ILL-DEFINED ZONES
C THAT ARE RELATIVELY HOMOGENEOUS IN THE DIRECTION OF LOCAL ASYMMETRY
C AND THAT HAVE BEEN FOUND USING METHODS DESCRIBED IN THE TEXT OF THIS
C PAPER.  IN THE LATER TWO CASES, THE PROGRAM WILL COMPENSATE TO SOME
C EXTENT FOR THE MISDRAWING OF STRATUM BOUNDARIES AND THE EXCLUSION OF
C A NEAREST NEIGHBOR REFERENCE ITEM OF ONE CLASS FROM THE STRATUM OF A
C BASE ITEM OF ANOTHER CLASS.  THE PROGRAM ADDITIONALLY REQUIRES THE USE
C OF THE SAME SET OF AREAL STRATA FOR ALL PAIRS OF ARTIFACT TYPES, UNDER
C THE ASSUMPTION THAT EACH STRATUM IS RELATIVELY HOMOGENEOUS INTERNALLY
C IN THE DIRECTION OF ASYMMETRY FOR EACH ARTIFACT CLASS PAIR CONTAINED
C IN IT.  THIS ASSUMPTION SHOULD BE CHECKED BEFORE THE DATA ARE ANALYZED
C WITH THIS PROGRAM.
C
C IN SKETCH, THE PROGRAM INVOLVES SEVEN BASIC STEPS.  (1) IT READS THE
C X AND Y COORDINATES AND STRATUM ASSIGNMENTS OF ALL ITEMS IN EACH
C ARTIFACT CLASS TO BE USED IN CALCULATING THE AVDISTLP1 COEFFICIENTS.
C (2) IT WRITES OUT VARIOUS INPUT VALUES AND SUMMARY STATISTICS THAT
C ALLOW THE USER TO CHECK WHETHER THE DATA HAVE BEEN READ CORRECTLY.
C INCLUDED AMONG THESE ARE THE NUMBER OF ITEMS PER CLASS IN ALL STRATA
C COMBINED AND THE NUMBER OF ITEMS PER CLASS IN EACH INDIVIDUAL
C STRATUM. THE LATTER STATISTICS ALSO ARE USEFUL IN EVALUATING THE
C DIRECTION AND DEGREE OF ASYMMETRY BETWEEN VARIOUS PAIRS OF ARTIFACT
C CLASSES IN EACH STRATUM AND HOW ASYMMETRY RELATIONS VARY OVER STRATA.
C (3) THE PROGRAM DETERMINES FOR EACH STRATUM HAVING ITEMS OF BOTH A
C GIVEN BASE CLASS AND A GIVEN REFERENCE CLASS WHETHER THE NEAREST
C NEIGHBOR ITEM OF THE REFERENCE CLASS FOR EACH ITEM OF THE BASE CLASS
C OCCURS WITHINTHE STRATUM.  THIS INFORMATION IS USED TO DETERMINE
C WHETHER THE STRATUM BOUNDARIES HAVE BEEN DEFINED APPROPRIATELY AND
C WHETHER ONLY INTRA-STRATUM DISTANCES BETWEEN ITEMS, OR BOTH INTRA-
C STRATUM AND INTER-STRATUM DISTANCES, SHOULD BE USED IN CALCULATING
C AVDISTLP1 COEFFICIENTS. (4) TO HELP THE RESEARCHER ASSESS THE
C APPROPRIATENESS OF THE STRATA BOUNDARIES HE HAS DRAWN AND TO ALLOW
C STEPWISE IMPROVEMENT IN THEIR DEFINITION AND THE RESULTS OF ANALYSIS,
C THE PROGRAM OUTPUTS A SERIES OF MATRICES--ONE FOR EACH STRATUM--
C SHOWING THE NUMBER OF ITEMS OF EACH BASE CLASS THAT HAVE NEAREST
C NEIGHBORS OF A GIVEN REFERENCE CLASS IN OTHER STRATA, ALL REFERENCE
C CLASSES CONSIDERED.  (5) THE PROGRAM CALCULATES AND OUTPUTS A SERIES
C OF ASYMMETRIC MATRICES--ONE FOR EACH STRATUM--CONTAINING THE AVDIST1
C AND AVDIST2 COEFFICIENTS FOR EACH BASE CLASS/REFERENCE CLASS PAIR.  IF
C A BASE CLASS IS NOT PRESENT IN A STRATUM, THE VALUE, 999.000, IS OUT-
C PUTTED FOR THE COEFFICIENT VALUES OF THAT BASE CLASS IN THAT STRATUM.
C (6) THE PROGRAM CALCULATES AND OUTPUTS A SERIES OF SYMMETRIC MATRICES
C --ONE FOR EACH STRATUM--CONTAINING THE WEIGHTS, X(J), FOR EACH BASE
C CLASS/REFERENCE CLASS PAIR THAT ARE USED IN CALCULATING THE AVDISTLP1
C COEFFICIENT FOR THAT PAIR.  (7) THE PROGRAM CALCULATES AND OUTPUTS A
C SYMMETRIC MATRIX CONTAINING THE AVDISTLP1 COEFFICIENTS FOR ALL PAIRS
C OF ARTIFACT CLASSES.
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C SYSTEM UNITS AND FILES LINKED TO THEM, AS REQUIRED BY THE PROGRAM:
C
C UNIT 1.  THIS UNIT SHOULD BE LINKED TO A FILE CONTAINING A 1 COLUMN X
C N ROW MATRIX OF THE NUMBER OF ARTIFACT OBSERVATIONS IN EACH ARTIFACT
C CLASS, IN THE FORMAT (1X,I4).  THE NUMBER OF ROWS, N, SHOULD EQUAL THE
C NUMBER OF ARTIFACT CLASSES.
C
C UNIT 2.  THIS UNIT SHOULD BE LINKED TO A FILE CONTAINING A 1 COLUMN X
C N ROW MATRIX OF THE NUMBER DESIGNATORS OF AREAL STRATA, IN THE FORMAT
C (1X,I4).  THE NUMBER OF ROWS, N, SHOULD EQUAL THE NUMBER OF AREAL
C STRATA.
C
C UNIT 3.  THIS UNIT SHOULD BE LINKED TO A FILE CONTAINING A 3 COLUMN X
C N ROW MATRIX OF THE X SPATIAL COORDINATES, Y SPATIAL COORDINATES, AND
C STRATUM AFFILIATIONS OF THE ITEMS OF ALL ARTIFACT CLASSES, IN THE
C FORMAT (F7.3,1X,F7.3,1X,F3.0).  THE NUMBER OF ROWS, N, SHOULD EQUAL
C THE NUMBER OF ALL ITEMS OF ALL ARTIFACT CLASSES.  THE ROWS OF
C COORDINATES AND STRATUM AFFILIATIONS SHOULD BE ARRANGED SEQUENTIALLY
C BY THE ARTIFACT CLASS OF THE ITEMS THEY REPRESENT, WITH THE ORDER OF
C CLASSES BEING THE SAME AS THAT IN THE FILE LINKED TO UNIT 1.  FOR
C CONVENIENCE, THE USER MAY WISH TO KEEP THE COORDINATES AND STRATUM
C AFFILIATIONS OF EACH ARTIFACT CLASS IN A SEPARATE FILE AND THEN STACK
C THE FILES INTO ONE MASTER FILE OF THE REQUIRED FORMAT.
C
C UNIT 6.  THIS UNIT SHOULD BE LINKED TO A FILE OR DEVICE TO RECEIVE
C OUTPUT MONITORING WHETHER THE NUMBERS OF ARTIFACT OBSERVATIONS IN EACH
C ARTIFACT CLASS, STORED IN A FILE ATTACHED TO UNIT 1, HAVE BEEN READ
C CORRECTLY.  THE OUTPUT ROUTED TO UNIT 6 IS THAT STORED IN THE FILE
C ATTACHED TO UNIT 1.
C
C UNIT 4.  THIS UNIT SHOULD BE LINKED TO A FILE OR DEVICE TO
C RECEIVE A NUMBER OF DIFFERENT KINDS OF MATRICES THAT:
C (A) MONITOR WHETHER THE DATA STORED IN THE FILE LINKED TO UNIT
C 3 HAVE BEEN READ CORRECTLY, (B) MONITOR THE PROGRESS OF THE
C PROGRAM, AND (C) ARE USED IN CALCULATING THE AVDISTLP1 COEFFICIENTS.
C THE FIRST MATRIX OUTPUTTED HAS N ROWS PERTAINING TO N AREAL
C STRATA AND M COLUMNS PERTAINING TO M ARTIFACT CLASSES (IN THE
C READ ORDER).  ITS ELEMENTS ARE THE NUMBER OF ITEMS OF EACH ARTIFACT
C CLASS IN EACH STRATUM.  TO ALLOW THE MATRIX TO BE DISPLAYED ON AN
C 80-COLUMN DEVICE, IF THE MATRIX IS GREATER THAN 10 COLUMNS, IT IS
C BROKEN INTO TWO OR THREE SUBMATRICES OF 10 OR LESS COLUMNS X N ROWS.
C THE SUBMATRICES ARE OUTPUTTED SEQUENTIALLY, SEPARATED BY BLANK ROWS.
C THE ELEMENTS IN EACH ROW OF THE MATRIX OR SUBMATRICES HAVE THE FORMAT
C J(1X,I4) WHERE J IS THE NUMBER OF ELEMENTS PER ROW (10 OR LESS).  THE
C MATRIX OR EACH SUBMATRIX IS PRECEDED BY 5 BLANK ROWS.
C
C NEXT ROUTED TO UNIT 4 ARE THREE SERIES OF MATRICES.  EACH SERIES
C CONTAINS AS MANY MATRICES AS THERE ARE AREAL STRATA--ONE FOR EACH
C STRATUM.  EACH MATRTIX OF EACH SERIES HAS N ROWS PERTAINING TO N BASE
C ARTIFACT CLASSES AND N COLUMNS PERTAINING TO N REFERENCE ARTIFACT
C CLASSES (IN THEIR READ ORDER).  EACH OF THE MATRICES IN THE FIRST
C SERIES HAS AS ELEMENTS THE NUMBER OF ITEMS OF A GIVEN BASE CLASS
C HAVING NEAREST NEIGHBORS OF A GIVEN REFERENCE CLASS OUTSIDE THE
C STRATUM TO WHICH THE MATRIX PERTAINS.  EACH MATRIX IN THE SECOND
C SERIES HAS AS ELEMENTS THE AVDIST1 AND AVDIST2 COEFFICIENTS FOR EACH
C BASE CLASS/REFERENCE CLASS PAIR, PERTINENT TO A GIVEN STRATUM.  EACH
C MATRIX IN THE THIRD SERIES HAS AS ELEMENTS THE X(J) WEIGHTS FOR EACH
C BASE CLASS/REFERENCE CLASS PAIR THAT ARE USED IN CALCULATING THE
C AVDISTLP1 COEFFICIENTS FOR THAT PAIR.  MATRICES PERTAINING TO STRATA
C IN WHICH A GIVEN ARTIFACT CLASS DOES NOT OCCUR, AND FOR WHICH AVDIST1
C COEFFICIENTS ARE UNDEFINED FOR BASE CLASS/REFERENCE CLASS PAIRS HAVING
C THAT ARTIFACT CLASS AS THE BASE CLASS, INCLUDE ELEMENTS WITH THE VALUE
C 999.000 FOR UNDEFINED AVDIST1 COEFFICIENTS.  TO ALLOW EACH MATRIX OF
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C EACH SERIES TO BE DISPLAYED ON AN 80-COLUMN DEVICE, IF THE MATRIX HAS
C MORE THAN 10 COLUMNS, IT IS BROKEN INTO TWO OR THREE SUBMATRICES OF
C 10 OR LESS COLUMNS X N ROWS, WHICH ARE OUTPUTTED SEQUENTIALLY.  THUS,
C THE THREE SERIES OF MATRICES ARE COMPOSED OF SEVERAL MATRICES--ONE FOR
C EACH STRATUM--WHICH IN TURN MAY BE COMPOSED OF TWO OR THREE SUB-
C MATRICES IN SEQUENCE.  WHEN EACH MATRIX IN EACH OF THE THREE SERIES
C IS 10 COLUMNS OR LESS AND NOT BROKEN INTO SUBMATRICES, EACH MATRIX IS
C PRECEDED BY 5 BLANK ROWS AND THEN THE STRATUM DESIGNATOR PERTINENT TO
C IT.  WHEN EACH MATRIX IN EACH SERIES IS BROKEN INTO SEQUENTIAL
C SUBMATRICES, ALL SUBMATRICES ARE PRECEDED BY 5 BLANK ROWS BUT ONLY THE
C LEAD SUBMATRIX IS PRECEDED BY A STRATUM DESIGNATOR, AS WELL.  THE
C MATRICES OR SUBMATRICES IN THE FIRST SERIES, SECOND SERIES, AND THIRD
C SERIES HAVE ROWS WITH ELEMENTS IN THE RESPECTIVE FORMATS OF M(1X,I4),
C M(1X,F7.3), AND M(1X,F7.3), WHERE M IS THE NUMBER OF ELEMENTS PER ROW
C (10 OR LESS).
C
C THE FINAL MATRIX ROUTED TO UNIT 4 HAS AS ELEMENTS THE AVDISTLP1 COEF-
C FICIENTS FOR EACH PAIR OF ARTIFACT CLASSES.  THE MATRIX HAS N ROWS
C AND N COLUMNS PERTAINING TO THE N ARTIFACT CLASSES, IN THE ORDER THEY
C WERE READ.  IF THE MATRIX HAS MORE THAN 10 COLUMNS, IT IS BROKEN INTO
C TWO OR THREE SUBMATRICES OF 10 OR LESS COLUMNS X N ROWS, WHICH ARE
C OUTPUTTED SEQUENTIALLY.  THE ELEMENTS IN EACH ROW OF THE MATRIX OR
C SUBMATRICES HAVE THE FORMAT M(1X,F7.3), WHERE M IS THE NUMBER OF
C ELEMENTS PER ROW (10 OR LESS).  THE MATRIX (OR EACH SUBMATRIX) IS
C PRECEDED BY 5 BLANK ROWS.
C
C DEFINITION OF VARIABLES, ARRAYS, AND LIMITATIONS OF THE PROGRAM:
C
C NPOINT(23).  THE ARRAY OF NUMBERS OF ITEMS IN EACH ARTIFACT CLASS, FOR
C      UP TO 23 CLASSES.  THE CONTENTS OF THIS ARRAY ARE READ FROM A
C      FILE LINKED TO UNIT 1.
C NCLASS.  THE NUMBER OF ARTIFACT CLASSES IN THE DATA SET.
C ISTRID(13).THE ARRAY OF NUMERIC IDENTIFIERS FOR EACH AREAL STRATUM,
C      FOR UP TO 13 STRATA.  THE CONTENTS OF THIS ARRAY ARE READ FROM A
C      FILE LINKED TO UNIT 2.
C NSTRAT.  THE NUMBER OF AREAL STRATA IN THE DATA SET.
C ART(3,140,23).  THE MATRIX OF 2 (X AND Y) SPATIAL COORDINATES AND A
C        NUMERIC STRATUM IDENTIFIER FOR EACH OF UP TO 140 ITEMS IN UP TO
C        23 ARTIFACT CLASSES.  THE CONTENT OF THIS MATRIX ARE READ FROM
C        A FILE LINKED TO UNIT 3.
C ISTRNM(23,13).  THE MATRIX OF NUMBERS OF ITEMS OF EACH ARTIFACT CLASS
C        IN EACH STRATUM FOR UP TO 23 CLASSES AND 13 STRATA.  THE
C        CONTENTS OF THIS MATRIX ARE OUTPUTTED TO A FILE LINKED TO UNIT
         4.
C INDEX(140,23,23).  THE MATRIX OF INDEX VALUES FOR EACH ITEM (AS A BASE
C        ITEM) INDICATING WHETHER ITS NEAREST NEIGHBOR OF EACH GIVEN
C        REFERENCE CLASS FALLS WITHIN ITS AREAL STRATUM.  THE INDEX HAS
C        THE VALUE OF THE STRATUM DESIGNATOR OF THE ITEM IF THE NEAREST
C        NEIGHBOR OF THE GIVEN REFERENCE CLASS FALLS WITHIN THE ITEM'S
C        STRATUM.  IT HAS THE VALUE, 77, IF THE NEAREST NEIGHBOR OF THE
C        GIVEN REFERENCE CLASS FALLS IN SOME OTHER STRATUM.  UP TO 140
C        ITEMS PER CLASS FOR 23 CLASSES ARE PERMISSIBLE.
C NOUT(13,23,23).  THE MATRIX OF THE NUMBER OF ITEMS OF A GIVEN BASE
C        CLASS WITHIN A GIVEN STRATUM HAVING NEAREST NEIGHBORS OF A
C        GIVEN REFERENCE CLASS OUTSIDE THE STRATUM.
C AVDIST(13,23,23).  THE ASYMMETRIC MATRIX OF INTRA-STRATUM AVDIST1 AND
C        AVDIST2 COEFFICIENTS FOR UP TO 23 ARTIFACT CLASSES AND 13 AREAL
C        STRATA.  THE COEFFICIENT IS UNDEFINED AND GIVEN THE VALUE
C        999.000 FOR EACH BASE CLASS/REFERENCE CLASS PAIR FOR WHICH THE
C        BASE CLASS DOES NOT OCCUR WITHIN THE STRATUM OF CONCERN.  THE
C        CONTENTS OF THIS MATRIX ARE OUTPUTTED TO A FILE LINKED TO
C        UNIT 4.
C POLYD(13,23,23).  THE SYMMETRIC MATRIX OF COEFFICIENTS, EACH DEFINED
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C       AS THE MINIMUM OF THE AVDIST1-AVDIST2 COEFFICIENT-PAIR
C       PERTINENT TO A GIVEN PAIR OF ARTIFACT CLASSES WITHIN A GIVEN
C       STRATUM.  UP TO 23 CLASSES AND 13 STRATA ARE PERMISSIBLE.
C POLYT(23,23).  THE SYMMETRIC MATRIX OF AVDISTLP1 COEFFICIENTS FOR
C       EACH PAIR OF ARTIFACT CLASSES, WITH UP TO 23 CLASSES POSSIBLE.
C       THE CONTENTS OF THIS MATRIX ARE OUTPUTTED TO A FILE LINKED
C       WITH UNIT 4.
C
C IN THIS PROGRAM, STRATUM DESIGNATIONS MUST BE INTEGERS OF 3 DIGITS OR
C LESS, OTHER THAN 77.  IF THE USER WISHES TO USE THE STRATUM NUMBER,
C 77, THIS NUMBER IN LINE 960 OF THE PROGRAM MUST BE ALTERED TO SOME
C INTEGER OTHER THAN THE STRATUM NUMBERS USED.
C
C IT IS POSSIBLE TO INCREASE THE PROGRAM'S LIMITS ON THE NUMBER OF
C ITEMS PER ARTIFACT CLASS TO 9999, THE NUMBER OF ARTIFACT CLASSES
C UP TO 30, AND THE NUMBER OF STRATA UP TO 999. THIS CAN BE DONE BY
C ADJUSTING THE LIMITS SET IN THE DIMENSION STATEMENT (LINES 10-30).
C ANY FURTHER INCREASE IN THESE PARAMETERS REQUIRES MORE BASIC PROGRAM
C MODIFICATIONS IN THE INPUT AND OUTPUT STATEMENTS (LINES 70, 90, 120,
C 180, 470-610, 1630-1800, 1820-2000, 2170-2340, 2490-2640).  IT IS
C ASSUMED THAT THE COORDINATES OF ITEMS RANGE BETWEEN -99.999 AND
C 999.999, THAT THE MINIMUM DISTANCE SEPARATING ANY PAIR OF ITEMS IS
C 100000, AND THAT THE MAXIMUM AVERAGE DISTANCE (AVDIST1, AVDIST2,
C AVDISTLP1) FROM ITEMS OF ONE CLASS TO ITEMS OF ANOTHER IS 999.
C
C THE EFFICIENCY OF THIS PROGRAM COULD BE INCREASED IN SEVERAL MANNERS
C TO ACCOMODATE LARGE NUMBERS OF ARTIFACTS PER CLASS AND/OR CLASSES,
C WITHIN SYSTEM-SPECIFIC CONSTRAINTS, IN SEVERAL WAYS.
C
C THIS PROGRAM WAS WRITTEN AND IS SUPPORTED BY:
C
C                          CHRISTOPHER CARR
C                          DEPARTMENT OF ANTHROPOLOGY AND
C                          INSTITUTE FOR QUANTITATIVE ARCHAEOLOGY
C                          UNIVERSITY OF ARKANSAS
C                          FAYETTEVILLE, AR 72701
C
C
C ***********************************************************************
C
C
      DIMENSION ART(3,140,23),NPOINT(23),ISTRID(13),ISTRNM(23,13),      INT00010
     1AVDIST(13,23,23),POLYD(13,23,23),XWEIGH(13,23,23),POLYT(23,23),   INT00020
     2INDEX(140,23,23),NOUT(13,23,23)                                   INT00030
C READ IN ARRAY OF NUMBER OF OBSERVATIONS IN EACH ARTIFACT CLASS        INT00040
C AND CALCULATE NUMBER OF ARTIFACT CLASSES                              INT00050
      KOUNT=0                                                           INT00060
      DO 10 I=1,9999                                                    INT00070
      READ(1,104,END=102)NPOINT(I)                                      INT00080
      KOUNT=KOUNT+1                                                     INT00090
      WRITE(6,104)NPOINT(I)                                             INT00100
   10 CONTINUE                                                          INT00110
  102 NCLASS=KOUNT                                                      INT00120
C READ IN ARRAY OF STRATUM NUMBER DESIGNATIONS AND CALCULATE NUMBER     INT00130
C OF STRATA                                                             INT00140
      KOUNT2=0                                                          INT00150
      DO 40 I=1,999                                                     INT00160
      READ(2,110,END=111)ISTRID(I)                                      INT00170
      KOUNT2=KOUNT2+1                                                   INT00180
   40 CONTINUE                                                          INT00190
  111 NSTRAT=KOUNT2                                                     INT00200
C READ IN ARRAY OF OBSERVED LOCATIONS OF ITEMS AND THEIR STRATUM        INT00210
C ASSIGNMENTS FOR EACH CLASS                                            INT00220
```

```
      DO 11 KLASS=1,NCLASS
      NPT=NPOINT(KLASS)
      DO 9 KPOINT=1,NPT
      READ(3,103)(ART(KCOOR,KPOINT,KLASS),KCOOR=1,3)
    9 CONTINUE
   11 CONTINUE
C DETERMINE NUMBER OF ITEMS OF EACH CLASS IN EACH STRATUM
      DO 603 ISTRAT=1,NSTRAT
      ISTRT=ISTRID(ISTRAT)
      DO 604 KLASS=1,NCLASS
      KOUNT=0
      ISTRNM(KLASS,ISTRAT)=0
      NPT=NPOINT(KLASS)
      DO 605 KPOINT=1,NPT
      IF(ART(3,KPOINT,KLASS) .EQ. ISTRT)KOUNT=KOUNT+1
  605 CONTINUE
      ISTRNM(KLASS,ISTRAT)=KOUNT
  604 CONTINUE
  603 CONTINUE
C WRITE NUMBER OF ITEMS OF EACH CLASS IN EACH STRATUM TO UNIT 4
      IF(NCLASS .LE. 10) GO TO 201
      IF(NCLASS .LE. 20) GO TO 202
      IF(NCLASS .LE. 30) GO TO 203
  201 WRITE(4,105)
      DO 680 ISTRAT=1,NSTRAT
      WRITE(4,109)(ISTRNM(KLASS,ISTRAT),KLASS=1,NCLASS)
  680 CONTINUE
      GO TO 41
  202 WRITE(4,105)
      DO 681 ISTRAT=1,NSTRAT
      WRITE(4,109)(ISTRNM(KLASS,ISTRAT),KLASS=1,10)
  681 CONTINUE
      WRITE(4,105)
      DO 682 ISTRAT=1,NSTRAT
      WRITE(4,109)(ISTRNM(KLASS,ISTRAT),KLASS=11,NCLASS)
  682 CONTINUE
      GO TO 41
  203 WRITE(4,105)
      DO 683 ISTRAT=1,NSTRAT
      WRITE(4,109)(ISTRNM(KLASS,ISTRAT),KLASS=1,10)
  683 CONTINUE
      WRITE(4,105)
      DO 684 ISTRAT=1,NSTRAT
      WRITE(4,109)(ISTRNM(KLASS,ISTRAT),KLASS=11,20)
  684 CONTINUE
      WRITE(4,105)
      DO 685 ISTRAT=1,NSTRAT
      WRITE(4,109)(ISTRNM(KLASS,ISTRAT),KLASS=21,NCLASS)
  685 CONTINUE
   41 CONTINUE
C CONSTRUCT INDICES FOR EACH ITEM INDICATING WHETHER ITS NEAREST
C NEIGHBORS OF GIVEN REFERENCE CLASSES FALL WITHIN ITS STRATUM.
C INITIATE DOS FOR OPERATING ON CLASS PAIRS OR A CLASS WITH ITSELF
      DO 12 ICLASS=1,NCLASS
      NPTB=NPOINT(ICLASS)
      DO 13 JCLASS=1,NCLASS
      NPTR=NPOINT(JCLASS)
      DO 900 ISTRAT=1,NSTRAT
      ISTRT=ISTRID(ISTRAT)
C INITIATE SEARCH FOR NEAREST NEIGHBOR OF SAME OR DIFFERENT CLASS,
C IN A SPECIFIED STRATUM, IF POSSIBLE.
C CHECK IF BASE CLASS OCCURS IN THE STRATUM.
      IF(ISTRNM(ICLASS,ISTRAT) .LE. 0) GO TO 900
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C INITIATE INCREMENTING OF ITEMS OF THE BASE CLASS AND CHECK IF THE
C BASE ITEM OCCURS IN THE STRATUM OF INTEREST
      DO 14 KPNTB=1,NPTB
      IF(ART(3,KPNTB,ICLASS)-ISTRT)14,901,14
C CHECK IF THE REFERENCE CLASS OCCURS IN THE STRATUM
  901 IF(ISTRNM(JCLASS,ISTRAT) .LE. 0) GO TO 950
C INITIATE INCREMENTING ITEMS OF REFERENCE CLASS, AND FIND NEAREST
C NEIGHBOR OF THAT CLASS IN ANY STRATUM (TO ACCOMODATE FOR INAPPRO-
C PRIATELY DRAWN STRATUM BOUNDARIES).  IF BOUNDARIES ARE APPROX-
C IMATELY APPROPRIATE, USUALLY THE NEAREST NEIGHBOR WILL BE IN THE
C STRATUM OF THE BASE ITEM.  NOTE THE STRATUM OF THE NEAREST NEIGHBOR
C OF THAT REFERENCE CLASS WITH AN INDEX VALUE EQUIVALENT TO THE STRATUM
C NUMBER.
      DMIN=100000.
      DO 50 KPNTR=1,NPTR
      DST=SQRT((ART(1,KPNTB,ICLASS)-ART(1,KPNTR,JCLASS))**2+
     1(ART(2,KPNTB,ICLASS)-ART(2,KPNTR,JCLASS))**2)
      IF(DST .LT. DMIN) GO TO 51
      GO TO 50
   51 DMIN=DST
      INDX=ART(3,KPNTR,JCLASS)
   50 CONTINUE
      INDEX(KPNTB,JCLASS,ICLASS)=INDX
      GO TO 14
  950 INDEX(KPNTB,JCLASS,ICLASS)=77
   14 CONTINUE
  900 CONTINUE
   13 CONTINUE
   12 CONTINUE
C INITIATE DOS FOR OPERATING ON CLASS PAIRS OR A CLASS WITH ITSELF
      DO 112 ICLASS=1,NCLASS
      NPTB=NPOINT(ICLASS)
      DO 113 JCLASS=1,NCLASS
      NPTR=NPOINT(JCLASS)
      DO 1900 ISTRAT=1,NSTRAT
      ISTRT=ISTRID(ISTRAT)
C SET VALUE FOR INTRA-STRATUM AVDIST STATISTIC AT 999, SHOULD THE BASE
C CLASS NOT OCCUR IN THE STRATUM.
      AVDIST(ISTRAT,JCLASS,ICLASS)=999.
      NOUT(ISTRAT,JCLASS,ICLASS)=0
      KOUNT2=0
      SUM=0.
C INITIATE SEARCH FOR NEAREST NEIGHBOR OF SAME OR DIFFERENT CLASS
C IN A SPECIFIED STRATUM, IF POSSIBLE.
C CHECK IF BASE CLASS OCCURS IN THE STRATUM.
      IF(ISTRNM(ICLASS,ISTRAT) .LE. 0) GO TO 1900
C INITIATE INCREMENTING OF ITEMS OF THE BASE CLASS AND CHECK IF THE
C BASE ITEM OCCURS IN THE STRATUM
      DO 114 KPNTB=1,NPTB
      IF(ART(3,KPNTB,ICLASS)-ISTRT)114,1901,114
C CHECK IF REFERENCE CLASS OCCURS IN THE STRATUM
 1901 IF(ISTRNM(JCLASS,ISTRAT) .LE. 0) GO TO 1950
C CHECK IF THE BASE ITEM HAS A NEAREST NEIGHBOR OF THE REFERENCE CLASS
C IN ANOTHER STRATUM
      IF(INDEX(KPNTB,JCLASS,ICLASS) .NE. ISTRT) GO TO 1950
C INITIATE INCREMENTING ITEMS OF REFERENCE CLASS AND CHECK IF
C THE REFERENCE ITEM OCCURS IN THE STRATUM.
      DMIN2=100000.
      DO 115 KPNTR=1,NPTR
      IF(ART(3,KPNTR,JCLASS)-ISTRT)115,1902,115
 1902 DST2=SQRT((ART(1,KPNTB,ICLASS)-ART(1,KPNTR,JCLASS))**2+
     1(ART(2,KPNTB,ICLASS)-ART(2,KPNTR,JCLASS))**2)
      IF(DST2 .LT. DMIN2) DMIN2=DST2
```

```
  115 CONTINUE                                                          INT01490
      SUM=SUM+DMIN2                                                     INT01500
      GO TO 114                                                         INT01510
C IF THE REFERENCE CLASS OCCURS IN THE STRATUM, INCLUDE IN SUM THE      INT01520
C DISTANCES BETWEEN BASE ITEMS HAVING NEAREST NEIGHBOR REFERENCE ITEMS  INT01530
C OUTSIDE THE STRATUM AND THOSE REFERENCE ITEMS. IF THE REFERENCE CLASS INT01540
C DOES NOT OCCUR IN THE STRATUM, FORM A SUM OF DISTANCES TO NEAREST     INT01550
C NEIGHBORS IN ANY STRATUM                                              INT01560
 1950 KOUNT2=KOUNT2+1                                                   INT01570
      DMIN3=100000.                                                     INT01580
      DO 215 KPNTR=1,NPTR                                               INT01590
      DST3=SQRT((ART(1,KPNTB,ICLASS)-ART(1,KPNTR,JCLASS))**2+           INT01600
     1(ART(2,KPNTB,ICLASS)-ART(2,KPNTR,JCLASS))**2)                     INT01610
      IF(DST3 .LT. DMIN3) DMIN3=DST3                                    INT01620
  215 CONTINUE                                                          INT01630
      SUM=SUM+DMIN3                                                     INT01640
  114 CONTINUE                                                          INT01650
      AVDIST(ISTRAT,JCLASS,ICLASS)=SUM/ISTRNM(ICLASS,ISTRAT)            INT01660
      NOUT(ISTRAT,JCLASS,ICLASS)=KOUNT2                                 INT01670
 1900 CONTINUE                                                          INT01680
  113 CONTINUE                                                          INT01690
  112 CONTINUE                                                          INT01700
C WRITE NUMBER OF ITEMS OF GIVEN BASE CLASSES HAVING NEAREST NEIGHBORS  INT01710
C OF GIVEN REFERENCE CLASSES OUTSIDE EACH STRATUM.                      INT01720
      DO 470 ISTRAT=1,NSTRAT                                            INT01730
      WRITE(4,105)                                                      INT01740
      WRITE(4,107)ISTRID(ISTRAT)                                        INT01750
      IF(NCLASS .LE. 10) GO TO 204                                      INT01760
      IF(NCLASS .LE. 20) GO TO 205                                      INT01770
      IF(NCLASS .LE. 30) GO TO 206                                      INT01780
  204 DO 471 ICLASS=1,NCLASS                                            INT01790
      WRITE(4,109)(NOUT(ISTRAT,JCLASS,ICLASS),JCLASS=1,NCLASS)          INT01800
  471 CONTINUE                                                          INT01810
      GO TO 470                                                         INT01820
  205 DO 472 ICLASS=1,NCLASS                                            INT01830
      WRITE(4,109)(NOUT(ISTRAT,JCLASS,ICLASS),JCLASS=1,10)              INT01840
  472 CONTINUE                                                          INT01850
      WRITE(4,105)                                                      INT01860
      DO 473 ICLASS=1,NCLASS                                            INT01870
      WRITE(4,109)(NOUT(ISTRAT,JCLASS,ICLASS),JCLASS=11,NCLASS)         INT01880
  473 CONTINUE                                                          INT01890
      GO TO 470                                                         INT01900
  206 DO 474 ICLASS=1,NCLASS                                            INT01910
      WRITE(4,109)(NOUT(ISTRAT,JCLASS,ICLASS),JCLASS=1,10)              INT01920
  474 CONTINUE                                                          INT01930
      WRITE(4,105)                                                      INT01940
      DO 475 ICLASS=1,NCLASS                                            INT01950
      WRITE(4,109)(NOUT(ISTRAT,JCLASS,ICLASS),JCLASS=11,20)             INT01960
  475 CONTINUE                                                          INT01970
      WRITE(4,105)                                                      INT01980
      DO 476 ICLASS=1,NCLASS                                            INT01990
      WRITE(4,109)(NOUT(ISTRAT,JCLASS,ICLASS),JCLASS=21,NCLASS)         INT02000
  476 CONTINUE                                                          INT02010
  470 CONTINUE                                                          INT02020
C WRITE INTRA-STRATUM AVDIST1 AND AVDIST2 COEFFICIENTS TO UNIT 4.       INT02030
      DO 615 ISTRAT=1,NSTRAT                                            INT02040
      WRITE(4,105)                                                      INT02050
      WRITE(4,107)ISTRID(ISTRAT)                                        INT02060
      IF(NCLASS .LE. 10) GO TO 207                                      INT02070
      IF(NCLASS .LE. 20) GO TO 208                                      INT02080
      IF(NCLASS .LE. 30) GO TO 209                                      INT02090
  207 DO 616 ICLASS=1,NCLASS                                            INT02100
      WRITE(4,106)(AVDIST(ISTRAT,JCLASS,ICLASS),JCLASS=1,NCLASS)        INT02110
```

```
 616  CONTINUE                                                          INT02120
      GO TO 615                                                         INT02130
 208  DO 617 ICLASS=1,NCLASS                                            INT02140
      WRITE(4,106)(AVDIST(ISTRAT,JCLASS,ICLASS),JCLASS=1,10)            INT02150
 617  CONTINUE                                                          INT02160
      WRITE(4,105)                                                      INT02170
      DO 618 ICLASS=1,NCLASS                                            INT02180
      WRITE(4,106)(AVDIST(ISTRAT,JCLASS,ICLASS),JCLASS=11,NCLASS)       INT02190
 618  CONTINUE                                                          INT02200
      GO TO 615                                                         INT02210
 209  DO 619 ICLASS=1,NCLASS                                            INT02220
      WRITE(4,106)(AVDIST(ISTRAT,JCLASS,ICLASS),JCLASS=1,10)            INT02230
 619  CONTINUE                                                          INT02240
      WRITE(4,105)                                                      INT02250
      DO 620 ICLASS=1,NCLASS                                            INT02260
      WRITE(4,106)(AVDIST(ISTRAT,JCLASS,ICLASS),JCLASS=11,20)           INT02270
 620  CONTINUE                                                          INT02280
      WRITE(4,105)                                                      INT02290
      DO 621 ICLASS=1,NCLASS                                            INT02300
      WRITE(4,106)(AVDIST(ISTRAT,JCLASS,ICLASS),JCLASS=21,NCLASS)       INT02310
 621  CONTINUE                                                          INT02320
 615  CONTINUE                                                          INT02330
C FIND MINIMUM AVDIST STATISTIC FOR EACH STRATUM, FOR EACH BASE CLASS/  INT02340
C REFERENCE CLASS PAIR.                                                 INT02350
      DO 18 ICLASS=1,NCLASS                                             INT02360
      DO 19 JCLASS=1,NCLASS                                             INT02370
      DO 20 ISTRAT=1,NSTRAT                                             INT02380
      XWEIGH(ISTRAT,JCLASS,ICLASS)=0.                                   INT02390
      POLYD(ISTRAT,JCLASS,ICLASS)=AMIN1(AVDIST(ISTRAT,JCLASS,ICLASS),   INT02400
     1AVDIST(ISTRAT,ICLASS,JCLASS))                                     INT02410
      IF(POLYD(ISTRAT,JCLASS,ICLASS) .EQ. AVDIST(ISTRAT,JCLASS,ICLASS)) INT02420
     1XWEIGH(ISTRAT,JCLASS,ICLASS)=ISTRNM(ICLASS,ISTRAT)                INT02430
      IF(POLYD(ISTRAT,JCLASS,ICLASS) .EQ. AVDIST(ISTRAT,ICLASS,JCLASS)) INT02440
     1XWEIGH(ISTRAT,JCLASS,ICLASS)=ISTRNM(JCLASS,ISTRAT)                INT02450
  20  CONTINUE                                                          INT02460
  19  CONTINUE                                                          INT02470
  18  CONTINUE                                                          INT02480
C WRITE WEIGHTS TO FILE                                                 INT02490
      DO 630 ISTRAT=1,NSTRAT                                            INT02500
      WRITE(4,105)                                                      INT02510
      WRITE(4,107)ISTRID(ISTRAT)                                        INT02520
      IF(NCLASS .LE. 10) GO TO 210                                      INT02530
      IF(NCLASS .LE. 20) GO TO 211                                      INT02540
      IF(NCLASS .LE. 30) GO TO 212                                      INT02550
 210  DO 686 ICLASS=1,NCLASS                                            INT02560
      WRITE(4,108)(XWEIGH(ISTRAT,JCLASS,ICLASS),JCLASS=1,NCLASS)        INT02570
 686  CONTINUE                                                          INT02580
      GO TO 630                                                         INT02590
 211  DO 687 ICLASS=1,NCLASS                                            INT02600
      WRITE(4,108)(XWEIGH(ISTRAT,JCLASS,ICLASS),JCLASS=1,10)            INT02610
 687  CONTINUE                                                          INT02620
      WRITE(4,105)                                                      INT02630
      DO 688 ICLASS=1,NCLASS                                            INT02640
      WRITE(4,108)(XWEIGH(ISTRAT,JCLASS,ICLASS),JCLASS=11,NCLASS)       INT02650
 688  CONTINUE                                                          INT02660
      GO TO 630                                                         INT02670
 212  DO 689 ICLASS=1,NCLASS                                            INT02680
      WRITE(4,108)(XWEIGH(ISTRAT,JCLASS,ICLASS),JCLASS=1,10)            INT02690
 689  CONTINUE                                                          INT02700
      WRITE(4,105)                                                      INT02710
      DO 690 ICLASS=1,NCLASS                                            INT02720
      WRITE(4,108)(XWEIGH(ISTRAT,JCLASS,ICLASS),JCLASS=11,20)           INT02730
 690  CONTINUE                                                          INT02740
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      WRITE(4,105)                                                      INT02750
      DO 691 ICLASS=1,NCLASS                                            INT02760
      WRITE(4,108)(XWEIGH(ISTRAT,JCLASS,ICLASS),JCLASS=21,NCLASS)       INT02770
  691 CONTINUE                                                          INT02780
  630 CONTINUE                                                          INT02790
C FIND COMPOSITE AVDISTLP1 STATISTIC FOR ALL STRATA                      INT02800
      DO 23 ICLASS=1,NCLASS                                             INT02810
      DO 24 JCLASS=1,NCLASS                                             INT02820
      SUM1=0.                                                           INT02830
      SUM2=0.                                                           INT02840
      DO 25 ISTRAT=1,NSTRAT                                             INT02850
      SUM1=SUM1+(XWEIGH(ISTRAT,JCLASS,ICLASS)*                          INT02860
     1POLYD(ISTRAT,JCLASS,ICLASS))                                      INT02870
      SUM2=SUM2+XWEIGH(ISTRAT,JCLASS,ICLASS)                            INT02880
   25 CONTINUE                                                          INT02890
      POLYT(JCLASS,ICLASS)=SUM1/SUM2                                    INT02900
   24 CONTINUE                                                          INT02910
   23 CONTINUE                                                          INT02920
C WRITE MATRIX OF AVDISTLP1 VALUES TO UNIT 4                             INT02930
      WRITE(4,105)                                                      INT02940
      IF(NCLASS .LE. 10) GO TO 213                                      INT02950
      IF(NCLASS .LE. 20) GO TO 214                                      INT02960
      IF(NCLASS .LE. 30) GO TO 216                                      INT02970
  213 DO 30 ICLASS=1,NCLASS                                             INT02980
      WRITE(4,106)(POLYT(JCLASS,ICLASS),JCLASS=1,NCLASS)                INT02990
   30 CONTINUE                                                          INT03000
      GO TO 38                                                          INT03010
  214 DO 31 ICLASS=1,NCLASS                                             INT03020
      WRITE(4,106)(POLYT(JCLASS,ICLASS),JCLASS=1,10)                    INT03030
   31 CONTINUE                                                          INT03040
      WRITE(4,105)                                                      INT03050
      DO 32 ICLASS=1,NCLASS                                             INT03060
      WRITE(4,106)(POLYT(JCLASS,ICLASS),JCLASS=11,NCLASS)               INT03070
   32 CONTINUE                                                          INT03080
      GO TO 38                                                          INT03090
  216 DO 33 ICLASS=1,NCLASS                                             INT03100
      WRITE(4,106)(POLYT(JCLASS,ICLASS),JCLASS=1,10)                    INT03110
   33 CONTINUE                                                          INT03120
      WRITE(4,105)                                                      INT03130
      DO 34 ICLASS=1,NCLASS                                             INT03140
      WRITE(4,106)(POLYT(JCLASS,ICLASS),JCLASS=11,20)                   INT03150
   34 CONTINUE                                                          INT03160
      WRITE(4,105)                                                      INT03170
      DO 35 ICLASS=1,NCLASS                                             INT03180
      WRITE(4,106)(POLYT(JCLASS,ICLASS),JCLASS=21,NCLASS)               INT03190
   35 CONTINUE                                                          INT03200
   38 CONTINUE                                                          INT03210
  103 FORMAT(F7.3,1X,F7.3,1X,F3.0)                                      INT03220
  104 FORMAT(1X,I4)                                                     INT03230
  105 FORMAT(/////)                                                     INT03240
  106 FORMAT(10(1X,F7.3))                                               INT03250
  107 FORMAT(10X,I3)                                                    INT03260
  108 FORMAT(10(1X,F4.0))                                               INT03270
  109 FORMAT(10(1X,I4))                                                 INT03280
  110 FORMAT(1X,I4)                                                     INT03290
   88 STOP                                                              INT03300
      END                                                               INT03310
```

For Concordance in Archaeological Analysis

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Christopher Carr
GENERAL EDITOR

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