SERIATION METHOD AND ITS EVALUATION

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ABSTRACT

Seriation as a scaling technique produces a formal arrangement of units, the significance of which must be inferred. Arrangement per se is a statistical matter, while the inference of significance is archaeological method. Here seriation as an archaeological method for inferring relative chronology is reviewed in terms of its assumptions and the conditions under which it is applicable. From this examination it is concluded that seriations may be inferred to be chronologies when and only when: (1) the comparisons are conducted using historical classes; (2) the units ordered are of comparable duration; (3) the units ordered are from the same cultural tradition; and (4) when the order is repeated through several independent seriations. The means of assessing whether or not a given seriation meets these conditions is considered in detail. Within specifiable limits seriations can be inferred to be chronologies, but these limits are more restricted than generally appreciated.

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Given the nature of the subject matter of prehistory, time is always an inferred dimension of the data. Unlike the situation faced by the sociocultural anthropologist, this dimension (Spaulding 1960) cannot be assumed by the prehistorian. As a result, chronology, the stipulation of the temporal dimension of a given body of data, is and has been of considerable importance to prehistory and the methods used by prehistory. Customarily, considerations of time are divided into two categories: absolute time and relative time. Absolute-dating methods stipulate the temporal dimension in terms of a unique position in a calendric system. A great many methods are available for such dating, and the number has increased rapidly in recent years. Importantly though, none of the techniques for absolute dating used by the prehistorian have their theoretical basis in anthropology; rather, they are drawn from the natural sciences such as physics. The primary use of absolute-dating methods is the correlation of local chronologies constructed by means of relative chronology.

Relative-dating methods stipulate the temporal dimension of the data by placing a given unit in a sequence of similar units. There are but two methods of this kind which are of general applicability, stratigraphy and seriation. Stratigraphy, as a method, has its foundations in geology in what is usually called the "law of superposition." Because superposition is applicable *only* to deposition units, i.e., geologic layers which are physically discrete, and because the notion of superposition is restricted to those situations in which one has a sequence of layers, stratigraphy is applicable *only* to single sites.

Seriation operates upon cultural material to establish chronology, and thus its theoretical framework lies within prehistory. Because seriation is not restricted to a single locality or to the same kind of unit as is stratigraphy, it has found much wider application to the problems of prehistory than other methods. Seriation and techniques for constructing seriations have been regularly treated in the literature for more than fifteen years (e.g., Brainerd 1951; Phillips, Ford, and Griffin 1951; Robinson 1951; Mayer-Oakes 1955; Meighan 1959; Brown and Freeman 1964; Kuzara, Mead, and Dixon 1966; Hole and Shaw 1967; Craytor and Johnson 1968; and Johnson 1968). Hole and Shaw in particular concern themselves with the efficacy of the several techniques available and some of the problems involved in seriation. Their work, coupled with its review by Cowgill (1968a) constitutes the single most comprehensive survey of technique. Recently the method has been reviewed historically by Rouse (1967) with specific reference to kinds of seriation and their application to different situations in prehistory. In addition, Deetz and Dethlefsen (1965) have focused on limited aspects of the method to point out some inherent problems in using class distributions.

Given the amount, variety, and depth of consideration that seriation has received, particularly in view of the comprehensive treatment by Rouse, it is not the intent here to review seriation in its entirety. Far too frequently in the past, however, seriation has been treated solely as a technique, rather than as a method. In employing two terms, method and technique, a distinction is drawn between a set of assumptions, their corollaries and relations, organized for the solution of a particular class of problem (e.g., chronology) here called a method, and the application of such a device to a specific set of data, introducing historical contingency in the form of specific types, counts of objects, sampling and the like, in order to produce the solution of a specific problem (e.g., the relative age of occupations 1 - 10). Only if such a distinction is made is it possible to separate a bad method from the misapplication of a good method or "bad practice."

In treating seriation as a technique, the assumptions made by the method are usually ignored. Not only has this resulted in applying seriation in situations in which the assumptions that it makes cannot be satisfied (Brown and Freeman 1964), but it also has effectively negated any ability to evaluate either the method itself or the results of any given seriation. Evaluation in most cases has amounted to an assessment of the abilities of the individual who has done the seriation. Recent improvements (e.g., Brainerd 1951; Robinson 1951; Meighan 1959; Kuzara, Mead, and Dixon 1966; and Hole and Shaw 1967) have been in technique, i.e., most effective or efficient ways to construct a seriation, and have not concerned themselves with the method, which is apparently *assumed* to be practical and useful. In turn, critiques of these studies (Craytor and Johnson 1968; Johnson 1968; and Cowgill 1968a, 1968b) have focused on the mechanics and evaluation of the statistical procedures involved. The basis for inferring the significance, be it chronological or otherwise, has been lost in the shuffle. The best ordering of a series of data may or may not be a chronology. The evaluation of this kind of inference is a matter of prehistory and not of statistics. The ultimate utility of technical improvements depends upon the utility of the method, and this, as noted by Hole and Shaw (1967:84-9), is not clearly demonstrated in the literature.

It is the intent of this paper to: (1) clarify those aspects of seriation which bear directly upon its evaluation as a method for the construction of relative chronologies; (2) to point out deficiencies incorporated in the present method; and (3) suggest means for rectifying such deficiencies as exist. The graphic technique for seriation as used by James Ford will be the focus of this treatment since its assumptions are most easily delineated. The Ford technique, in spite of its numerous critics, presents far more information than do the comparable statistical techniques. Not only is the degree of similarity between two units indicated, but the actual form and source of the similarity is shown as well. A Brainerd-Robinson seriation can always be constructed from the information contained in a Ford seriation, but graphic seriations cannot be constructed from a matrix of similarity coefficients. The relationship of the statistical techniques to the Ford technique will be explicitly treated in those areas in which it may not be obvious. The choice of the graphic technique should not be construed as a rejection of the statistical forms, only that the Ford technique is more amenable to the kind of examination undertaken here.

Rouse's explicit definition provides a useful starting point. Attention is directed to seriation as a problem-oriented archaeological method rather than as a technical procedure and the several "elements" involved in the method are carefully enumerated. Seriation, according to Rouse, is "*. . . the procedure of working out a chronology by arranging local remains of the same cultural tradition in the order which produces the most consistent patterning of their cultural traits*" (1967:157). This definition is, however, only a starting point, for it is unsatisfactory in several important respects (e.g., the definition presumes that the best order is a chronology) and some of the terms (e.g., "traits") admit more vagueness than is desirable. In the same article Rouse recognizes three kinds of seriation (1967:178-92). "Occurrence seriation" makes use of presence and absence patterns for ordering; "frequency seriation" employs patterns of frequency of occurrence for the same task. The third kind distinguished by Rouse, "developmental seriation," is not a method for ordering, but given a known order, it is a means of identifying units with the order. The inclusion of developmental seriation in Rouse's survey is perfectly reasonable; however, it will not be treated herein where the emphasis is on the orders themselves. In the following considerations the term seriation will be used to include both the occurrence and frequency types and the statistical forms most usually allied to frequency seriation.

Since much of the following discussion assumes classes and classification, a subject matter far too complex for consideration here, a statement of the position taken with respect to them is necessary. The term class should be taken to mean a paradigmatic class (typological if you prefer) with an intentional definition (e.g., Conklin 1964:40). Classes are conceptual units. The relationship of such constructs to phenomena and the terminology for these relationships follows that of Morris (1938) and Lounsbury (1964:1073-4). Briefly, the definition of a class, the necessary and sufficient conditions for membership, comprises a set of distinctive features collectively termed the *significatum* of the class. Phenomena are *identified* as members of a given class when they display attributes indicated as necessary and sufficient conditions in the class significatum. An attribute, object, or set of objects identified as a member of a class is a *denotatum* of that class. Stating that object X is a member of Class A says only that X displays the attributes required by the significatum of Class A. The other attributes of X may or may not be held in common by other objects assigned to Class A; non-definitive attributes are variable. In a very real sense, the meaning of a class is the significatum. Thus when talking about distributions of classes (actually their denotata), what is being mapped is the occurrence of a particular combination of attributes in objects and not sets of objects. Attributes, objects, or sets of objects have locations in time and space and not distributions. It is for this reason that classes are important in the discussion of seriation, a device which makes use of distributions. The term *group* will be used here to denote aggregates of phenomena, be they conceived of as attributes, objects, or sets of objects. The term group has been chosen for even when one wishes to seriate single objects, those objects must be treated as groups or sets of attributes. Quite obviously there are many ways to create groups. In the case just mentioned, the physical discreteness of an object "groups" its constituent attributes. Identification of phenomena with classes in a classification is one means of creating groups, a means which provides an explicit statement in the form of the class definitions of the rules by which the groups have been formulated. The *denotata* of a class thus constitute a special kind of group, one with an explicit meaning. This particular view of classification is not requisite for the model of seriation to be presented, but the terminology of course is. This view is required if a given seriation is to be used to order material not included in the original seriation, a rather common practice in the case of Ford type seriations.

THE METHOD AND ITS ASSUMPTIONS

Rouse (1967) distinguishes the items actually ordered as the "units" of a seriation and the means by which the ordering is done as the "criteria." Johnson (1968:2) makes an analogous distinction between "individuals" (units) and "characters" (criteria). This is an important distinction which requires consideration. The units of a seriation must display two characteristics. First, the units must always have the characteristics of a group, that is, they must be phenomena conceived as physical aggregates of either attributes, objects, or sets of objects. The groups which can be seriated are thus groups of attributes (discrete objects), groups of objects (collections, assemblages, deposits, etc.) and, conceivably, groups of collections. Commonly, the units employed are groups of objects whose constituent members are single objects.

Secondly, the units of a seriation must always be conceived as events rather than objects (Rouse 1967:158). The reason for this second stipulation is obvious. Objects as objects cannot be dated, for they persist from the time of their creation to the present. In a formal sense, a single kind of event is dated by seriation regardless of the interpretation of the event or whether the units are single objects, collections, or groups of collections. The event dated is always the creation of the group, the time at which the various constituents of the group came together as a physical aggregate. Clearly, too, the event is a mean between the earliest and latest additions to the group. The temporal range between first and last additions is the duration of the unit. In the case of single objects, this event, often inferred to be manufacture or fabrication, is the time at which the attributes come together to make up the object. The duration of these units is typically minimal. Similarly in the case of collections, the event dated is the mean time at which the various objects which constitute the collection came together as a group (e.g., time of deposition). The duration of these units is variable but usually of a larger magnitude than in the case of objects. As emphasized, albeit somewhat differently, by Johnson (1968), the important thing to note is that a formal or "descriptive" event is measured and what the event means must be inferred as a separate procedure. Of course, in any given seriation, the groups must be of the same kind.

The criteria of seriation, the devices by means of which groups are to be ordered, must always have the characteristics of classes; that is, they must be defined conceptual categories capable of occurring in more than one place simultaneously. The constituent parts of the groups (e.g., the objects which make up a collection) are identified as denotata of classes. Classes provide the basis for comparing groups and simultaneously state in their significata the precise elements which constitute comparability in each case. What is recorded in a seriation is not the occurrence of objects but the distribution of combinations of features that the objects display as attributes. If the definitions of the classes are changed, the distributions will change and a new ordering result. This focuses attention upon the construction of classes used in seriation, especially the choices made in the formal elements of definition. At this point the only specification required is that the elements must have limited distributions in time. A wide variety of classes have been employed for these purposes, types being the kind most frequently used. When types have been created especially for seriation (i.e., defined by elements of limited duration) they are often termed historical, stylistic, or temporal types.

Typically, graphic presentations show the groups as horizontal rows and the classes as vertical axes. The intersection of a vertical axis and an horizontal row is represented by a sign indicating either the presence or absence of denotata of that particular class at that particular locality, or, if present, the relative number of objects at that locality which are denotata of the particular class. Statistical presentations, while based on this information, do not show either classes or groups but only a summary of the comparison of all of the groups with each other conducted in terms of the classes. It is this loss of information that makes the statistical presentations less useful than the graphic forms for the purpose attended here. Irrespective of the manner of presentation, however, *seriation is a method which uses classes to order groups*. The order is strictly formal. Its significance must be inferred.

Occurrence and frequency seriation differ in the way in which classes are employed to create the ordering. Further, the circumstances under which each is the most suitable approach varies (Lipe 1964; Rouse 1967), but this is not of direct concern here. Since occurrence seriation is the simplest of the two, making but a single assumption, it is best considered first. With this method the units to be ordered are recorded as the list of classes represented in the unit. For example, if types are the classes employed to order collections, then each collection is recorded simply as a list of types present. The frequency of occurrence is unimportant, and notation is made solely in terms of presence or absence. Fig. 1 represents such a seriation. The squares in any horizontal row constitute the group or unit labeled to the side; the vertical axes passing through the figure constitute the classes employed. The order of the units, which constitutes the actual seriation and which is presumed to be chronological, is achieved by arranging the groups so that the distribution of the denotata of the various classes is as continuous as possible along the vertical axes. The single theoretical principle upon which the method of occurrence seriation rests can be phrased as: *the distribution of any historical or temporal class is continuous through time.* It is on the basis of this assumption that ordering by means of occurrence seriation is presumed to be chronological. The order is not, ipso facto, chronological, but it is inferred to be chronological on the basis of the

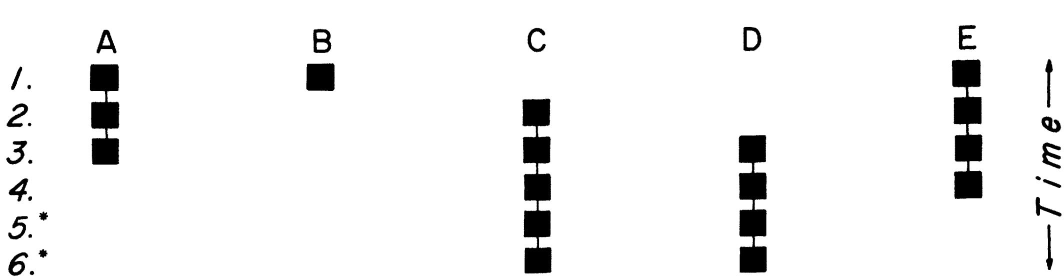

Fig. 1. An occurrence seriation ordering six groups (1 - 6) by means of five classes (A - E) in terms of presence (black squares) and absence of the denotata of the classes in the groups. The relative order of groups 5 and 6 is arbitrary and could be reversed.

above stated assumption and only when the assumption can be reasonably held to be true may the seriation be regarded as a chronology.

Not infrequently this principle is related to a notion of the "uninventiveness of man"; however, this kind of linkage between a theoretical proposition and an empirical generalization is unnecessary. Classes *can* be created so that their distribution is continuous through time and such classes are those used in seriation. This is the point to restricting the kind of classes used to those which are "historical" or "temporal."

Invoking this assumption creates a distributional model. The link between serial ordering and chronology is stipulated as a formal condition which such orders must meet. This is occurrence seriation as a method. Groups are arranged so that they conform to the pattern required by the assumption, and once this has been accomplished the order can be presumed chronological. As a technique, in the application of this model to real data using specific classes, the procedural statement must be modified to take into account contingencies of the phenomenological world. Actual procedure is to arrange the groups so that they approximate the continuous distribution pattern as closely as possible. Only by accident will it be possible to match the model exactly. Apart from special problems (e.g., differential preservation of objects belonging to different classes), tolerable deviation from the model is restricted to the effects of sampling error. Discontinuous distributions are to be expected for sparsely populated classes and at the beginnings and ends of distributions. Thus in practice an occurrence seriation is assumed to be chronological when the only deviation from the model of continuous distribution is in those areas predictable on the basis of sampling error.

Frequency seriation employs the assumption of continuous distribution but adds a stipulation about frequency of occurrence or "popularity" of the denotata of the classes used through time. For this method, groups must be recorded as the relative frequency of denotata of each class present. A given group or unit is thus not recorded simply as Classes A, B, E, G, but as 20% A, 30% B, 10% E, and 40% G (Fig. 2). Frequency seriation arranges groups not only so that each class has

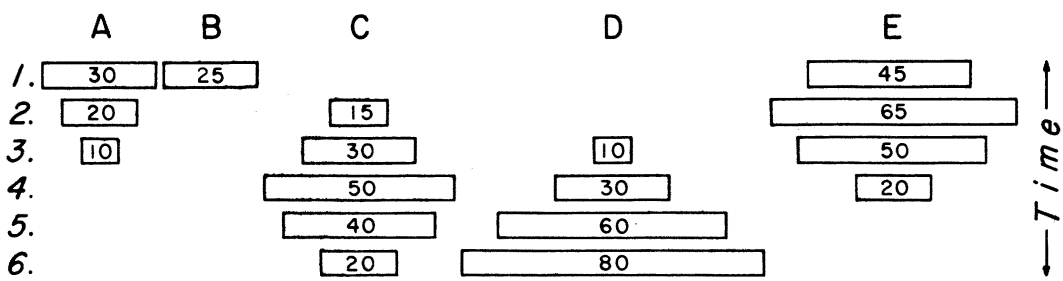

Fig. 2. A frequency seriation ordering six groups (1 - 6) by means of five classes (A - E) in terms of the frequency of occurrence of the denotata of the classes in the groups. The numbers in the bars represent the percentage of the total of each group belonging to each class.

continuous representation in the series of groups being ordered but also so that each continuous distribution exhibits the form of a unimodel curve in terms of the frequency of representation (Fig. 2). The additional assumption made in frequency seriation can be phrased as: *the distribution of any historical or temporal class exhibits the form of a unimodal curve through time*. The rationale for this assumption is that any idea or manifestation of an idea has an inception, a rise in popularity to a peak, and then a decrease in popularity to extinction (Rouse 1939:14; Ford 1949:407; Phillips, Ford, and Griffin 1951:220). Again it should be emphasized that in making this assumption one is not asserting that the real world invariably operates in this fashion, rather only that the classes used in seriation may be conceived so as to have this kind of distribution. For example, a given class might exhibit two peaks through time upon initial formulation. Such a class cannot be legitimately used in a seriation if only because it is not comparable to the other classes used. It can, however, be reformulated by examining the denotata constituting each peak, contrasting them in terms of consistent differences, and then the class redefined as two classes incorporating in their definitions the consistent differences observed. It might be argued that other kinds of distributions might serve the purposes of seriation equally well; however, the unimodal curve is the one traditionally used, and it is important that all the classes in a given seriation exhibit the same kind of distribution.

As with occurrence seriation, the assumption creates a distributional model. In any application to the phenomenological world, sampling error acts to skew actual distributions, but in a predictable manner. Actual ordering is accomplished by arranging the groups so that, with allowances made for deviation introduced through sampling, the class distributions approximate the required pattern. The order resulting is strictly formal; it must be *inferred* to be chronological, and this inference is based upon the assumption stated above.

Statistical techniques of seriation usually operate on data conceived in the manner here stipulated for frequency seriation, the major exception being the technique proposed by Dempsey and Baumhoff (1963). In the case of frequency seriation the data, as recorded, are entered row by row (group by group) into the distributional model and are visually compared with one another in terms of the mode. Statistical techniques compare the groups with each other prior to being compared with an ordering model. The results of the initial comparisons are recorded as a matrix of coefficients of similarity of one sort or another depending on the kind of comparison conducted and the means anticipated for comparison to an ordering model. Then the *coefficients*, not the data, are ordered so that all the highest values cluster *along* the axis of identity in the matrix. The assumption apparently employed in the ordering can be phrased: *units which are most similar to one another in terms of historical or temporal classes are closest together in time*. Here too, application to real problems introduces sampling error and acts to skew the distribution of high values, a condition usually termed "stress." There is no reason to believe that the results obtained by ordering units by means of "similarity" will differ significantly from results obtained by visual "patterning," if, and only if, the assessments of similarity embodied in the coefficients of similarity are based upon a comparison of groups in terms of historical or temporal classes. It is unfortunate that many writers using the statistical technique, Cowgill (1968b) being an outstanding exception, ignore the crucial role of the classes and focus on the statistics. This has tended to lend the impression that the statistical techniques are "better" than the visual ones rather than simply more efficient. A linear pattern of coefficients of similarity, like the approximation to a distributional model, must be *inferred* to be a chronology, and all such inferences must be based on the assumptions of the method and, ultimately, on whether or not the classes chosen for a seriation embody in their definitions criteria that vary primarily through time and not through other dimensions.

For example, if a randomly selected set of classes were used to examine groups of artifacts coming from a set of seasonal camps over an extended period of time, both the statistical techniques and the visual ones might arrange the various groups by function (e.g., winter camp–spring camp, etc.) and not according to time, or, even worse, an inseparable hodgepodge of both (Brown and Freeman 1964). In any case, there would be no basis for making an inference that the resultant order represented a chronology of the units. Since both the statistical and visual kinds of frequency seriation differ only in the technique of ordering and not fundamentally in the means by which the order is achieved, the two may be considered as alternative ways of executing a frequency seriation.

Seriations are strictly formal orders irrespective of the kind of seriation or the form of presentation. They must be inferred to be chronologies, and these inferences in turn are based upon the assumptions outlined above. Thus any seriation is, in effect, a pair of linked hypotheses, the actual execution of the seriation a test of the hypotheses. First, a seriation makes the hypothesis that the assumptions of the method may be held to be true in the particular circumstances of application. This requires the identification of the conditions under which the assumptions are operative and then an assessment of whether or not they obtain in a given case. Second, a seriation makes the hypothesis that the classes used are indeed "historical" or "temporal" classes. To infer that a given seriation is a chronology requires that both of these hypotheses be satisfied. The means of testing these hypotheses is the subject of the remainder of the paper.

CONDITIONS OF APPLICATION

While it is recognized in the literature that classification and classes play important roles in seriation, the focus of concern is on the conditions that the groups to be seriated must meet, essentially the first hypothesis made by the method. Moreover, these conditions, matters which ought to be empirically testable, are not usually differentiated from the assumption upon which the method operates (e.g., Ford 1949:38-40; Phillips, Ford, and Griffin 1951:219-23). As a consequence it is difficult to differentiate inconsistencies and failures of the method itself from its misapplication.

Insofar as a seriation is a special kind of structured comparison, the conditions which must be satisfied by the groups to be compared are nothing more than statements of their comparability for the purposes of seriation. Obviously, these conditions are directed toward stating that all of the groups included in a seriation *as recorded* are identical save in their relative temporal position. These conditions have been extensively treated in the literature, and although the number varies from author to author as do the names given them, the conditions are reducible to three in number. All that needs to be done here is to isolate and summarize each.

1. *All groups included in a seriation must be of comparable duration.* Ford (Phillips, Ford, and Griffin 1951:223) touches on this condition when he asserts that all the groups to be seriated have to be of short duration. Rouse (1967:162) rightly amends this statement by pointing out that it is not necessary that the groups represent short periods of time but rather equivalent or comparable periods of time. The shorter the duration of the groups, the finer the discriminations that the seriation will be able to make. When met, this condition assures that the distributions used in the seriation are not a function of variation in the duration of the groups but are due to their temporal position.

2. *All the groups included in a seriation must belong to the same cultural tradition*, that is, they must be "genetically" related. Ford considers this condition when he insists that one has to assume: a) a stable population over the period of time being considered; and b) that this period of time is represented by gradual change (Phillips, Ford, and Griffin 1951:223). These two stipulations effectively rule out migration. Both Rowe (1961:3326) and Rouse (1967:173-77) go further than Ford, realizing that two groups of people may have lived in the same area over the same period of time but have participated in unrelated stylistic developments, and thus they note that one must be able to assume a "genetic" relationship or continuity between all of the units. Since seriation makes use of cultural classes to order groups, this condition attends the relevance of a single set of classes to all the groups included in a seriation. When met by a series of groups, this condition assures that the distributions used by seriation are not the result of different stylistic traditions.

3. *All the groups included in a seriation must come from the same local area.* Both Ford (Phillips, Ford, and Griffin 1951:223) and Rouse (1967:177-79) note that diffusion through space can affect the distributions used by seriation. As a result, the groups incorporated in a seriation must be selected in such a manner as not to include variation in the spatial dimension. The notion of local area is defined by Rouse (1967:178) as ". . . a clustering of sites within which it is reasonable to suppose that there has been little, if any, geographic variation in culture. . ." and he goes on to suggest ways of delineating such areas in specific situations. The notion of local area, then, is intended to eliminate spatial variation. If all of the groups included in a seriation are drawn from the same local area, it can be assumed that the distributions used by seriation are not a function of spatial variation.

Seriation, then, is a method of ordering groups by means of a set of classes for the expressed purpose of chronological inference, and the ordering is accomplished by arranging the set of groups so that the classes have continuous distribution, and if the frequency of occurrence of denotata is noted, the frequencies take the form of unimodal curves. Such an order can be presumed to be a chronological order only when the groups seriated: a) represent comparable durations of time; b) belong to the same cultural tradition; and c) are drawn from a single local area.

EVALUATION

Insofar as the assumptions on which the various kinds of seriation operate are simple, indeed reducible in number to one, and their application does not involve logical contradiction, the operating assumptions may be regarded as logically true and the method both parsimonious and elegant. As should be apparent from the preceding section, however, meeting the conditions for application is not simple and clear-cut. Further, simply identifying the conditions is not testing whether or not they obtain in a given case, and there is a conspicuous lack of such testing in the literature. The general approach is to regard these conditions as the "normal" state of affairs and to act as if there are no conditions of application unless one is forced by circumstance to do otherwise. Yet, clearly, unless the conditions as outlined are met, a given seriation cannot reasonably be employed as the basis for inferring a chronology. Means of assessing each of the conditions which groups must meet are discussed in order below.

1. *All the groups included in a seriation must be of comparable duration.* It cannot be assumed *a priori* that all groups in a given seriation represent roughly equivalent periods of time, although there is some tendency in the literature to regard surface collections in this manner. Furthermore, short of a very fine absolute chronology (e.g., Deetz and Dethlefsen's dated gravestones), which obviates the need for a seriation, it is not possible to evaluate objectively groups with regard to this condition before the groups have been seriated.

A more profitable way to look at the problem is to ask how much variation can be admitted before the groups are no longer comparable in duration *for the purposes of a given seriation*. The answer to this is fairly simple: variation cannot be so great as to affect the distribution of the denotata of the classes used to create the ordering. Variation less than this magnitude is obviously irrelevant for the purposes of seriation. This level of variability in the duration of groups can be assessed after a seriation has been attempted. If the variation is of such a magnitude as to affect the distributions, the units will either not seriate at all (in the case that many groups are not of comparable duration) or a few groups will be at substantial variance with the model stipulated by seriation (Fig. 3). Because variation from this source of non-comparability is random in relation to

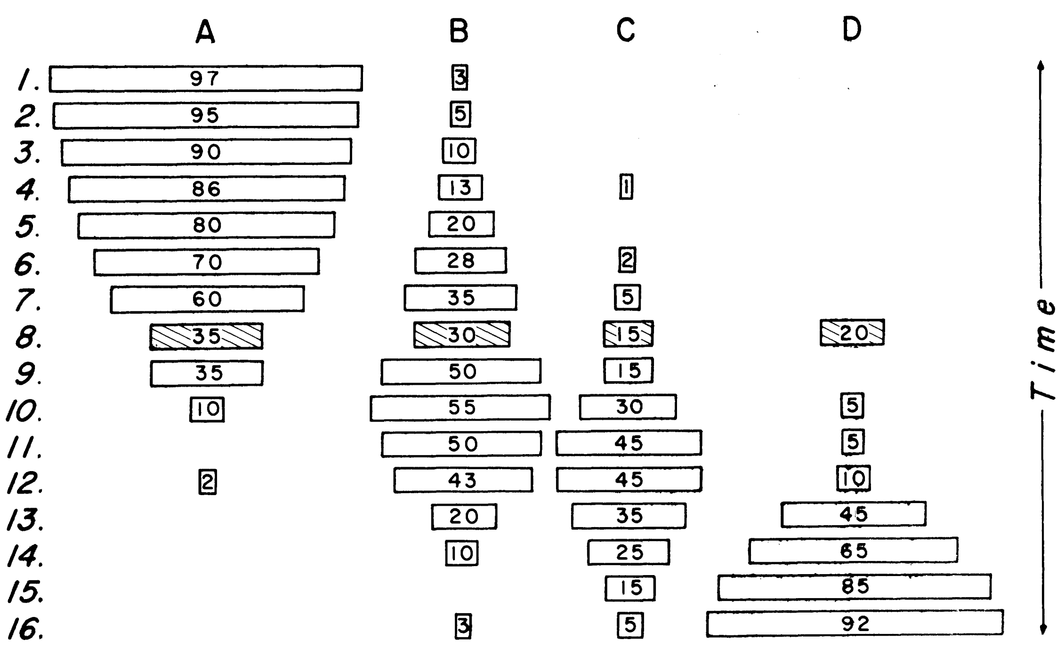

Fig. 3. The effect upon the seriation pattern of one group or unit not of comparable duration with the remainder of the included units. A-D are the classes, 1-16 are the groups of which 8 is the non-comparable unit.

the pattern of the seriation model, it will tend to destroy the pattern of unimodal curves and/or continuous distributions. If groups which are at substantial variation with the model are removed, a seriation cannot be made to yield a non-chronological ordering because of the non-comparability of duration of the groups seriated. Variation from the model can be tolerated only where it is predictable, namely at the beginnings and ends of distributions and in sparsely populated classes. A great many published seriations, however, include groups which do not closely conform to the model, and in these cases the inference that the seriation is a chronology is not well founded, at least for the groups at variance with the model.

Non-comparability of duration will affect the distributional patterns of a frequency seriation before it will affect the continuous distributions of an occurrence seriation. Frequency seriations make unique assignments, whereas occurrence seriations group the units considered. Thus occurrence seriation permits more variability in duration of groups seriated than does frequency seriation. In those cases in which a frequency seriation cannot be successfully accomplished, it is possible that an occurrence seriation using the same set of classes will successfully order a given set of groups. Important for our consideration is simply that seriation cannot yield substantially "wrong" orders, orders which are not chronological, because of non-comparability of included groups, and thus this condition can be assumed to have been satisfied any time that a seriation can be executed.

2. *All the groups in a seriation must belong to the same cultural tradition.* It is impossible to assert *a priori* that a given set of groups to be included in a seriation belong to the same cultural tradition. What constitutes the cultural comparability that is embodied in the notion of belonging to the same cultural tradition? All that is required *for the purposes of a given seriation* is that the set of classes employed to do the ordering be relevant to all the units. Because it is not necessary that any given unit share classes with any other specified unit (e.g., units A and O in Fig. 3), it is not easy to assess whether this condition is met in the data before seriation. It is possible, however, to ascertain whether the units meet this criterion after they have been seriated. If more than one tradition is represented in the groups, the application of the seriation model will produce as many independent orders as there are traditions represented, though, of course, on the same sheet of graph paper (Fig. 4). The results of seriating groups which do not fulfill this condition will be non-productive as was the case with the first condition, and thus recognizable.

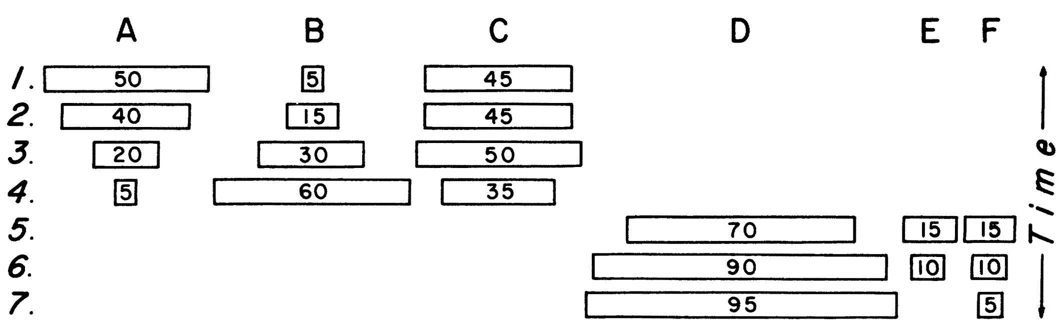

Fig. 4. Two independent orders resulting from the seriation of groups drawn from two different stylistic traditions. A - F are the classes and 1 - 7 are the groups. The placement of 5 - 7 at the bottom of the chart is arbitrary and they could have been placed at the top of the chart with equal justification.

It should also be noted that if the groups are not distributed more or less evenly throughout the segment of time represented by the seriation, a similar result will accrue, namely a disjunction creating two or more independent segments within a single graph. It is not so important to note the results of seriating units which represent two or more cultural traditions, but rather that if the seriation does produce a single order, this order may be taken as evidence that this second condition of application has been met by the groups included.

3. *All groups in a seriation must come from the same local area.* Superficially, this condition seems possible to satisfy before a set of groups is selected simply by reference to a map showing the location of the groups in space relative to one another and perhaps to physiographic and

environmental boundaries. If, however, one considers what the application of this criterion is to accomplish, namely to eliminate variation through the dimension of space, the problem becomes more complicated. For the purposes of seriation, it would be necessary to demonstrate that within such a "local area" each and every point in time at any location has precisely the same set of occurrence of denotata of the classes used in the seriation and in precisely the same proportion. Clearly this cannot be assumed *a priori* and furthermore is inconceivable.

The notion of "local area" is diametrically opposed to the very assumptions on which seriation operates. Seriation's assumptions are predicated on continuous variation in the formal dimension through time. Space is an analogous dimension (e.g., Spaulding 1960), and the notion of "local area" is predicated on discontinuous variation through space, or more accurately for the problem at hand, blocks of space in which there is no variation. It is simply inconceivable that variation of form does not occur simultaneously along both temporal and spatial dimensions.

Brown and Freeman (1964) in their study of ceramics from the Carter Ranch pueblo have pointed out that variation can and does occur not only as a function of temporal difference and sampling errors but also other dimensions. The only other source beyond time and sampling they discuss is "function." This consideration is far too simplified to be of much use beyond pointing out that, even if the first two criteria for application are satisfied, there yet remain other sources of variation in addition to time that affect distributions. Function varies through time along with form.

In a more controlled study, Deetz and Dethlefsen (1965) have demonstrated, using dated New England gravestones, that samples of known duration and drawn from the same cultural tradition cannot be assumed to be homogeneous through the dimension of space at any given point in time. These authors did not construct a seriation, but used already dated groups and examined the distribution of the denotata of classes on which seriations are based. The most important result of the study is that if the authors had constructed a seriation, the resultant order would not have been a chronology, but a set of distributions which combined both time and space as important sources of variation.

In my own work in eastern Kentucky (Hanson, Dunnell, and Hardesty 1964; Dunnell 1967) the problem created for the seriation method by variation through the spatial dimension is illustrated even more clearly. It is possible to suggest on the basis of the information recovered that homogeneity of the sort required by seriation phrased in terms of "local area" cannot be assumed even for parts of the same community. In this case about 80 percent of a small, stockaded, late prehistoric settlement was excavated. The community consisted of a series of rectangular houses arranged circularly around the inside of the stockade so as to leave an open plaza in the center. The site appears to have been occupied for a period of time, abandoned in favor of some other locality, and then reoccupied. This pattern of settlement is the expected one for farming peoples making use of swidden techniques in areas of restricted arable land. Artifacts were collected by excavation unit (2 meters by 2 meters, by 25 cm.). The differences in frequency of occurrence of ceramic types are greater within the same level from one part of the community to another than they are between the uppermost and lowermost levels in any part of the site. It is reasonable to assume that these horizontal differences do not represent time since the entire community had to be occupied simultaneously for the site to be functional. Half a stockade is as good as no stockade. It was possible to characterize one portion of the site as conservative in terms of ceramic change and another as progressive since the direction of ceramic change is known from vertical distributions. This same phenomenon was identified for other categories of data as well (e.g., manners of burial). Had two pits from different parts of this site been included in a seriation along with samples representing other villages in the immediate vicinity, these two pits would have been placed at opposite ends of the seriation.

The important conclusion to be drawn is that it is erroneous to assume, even at the level of a single community, that two points in space will be identical in the presence and absence or frequency of occurrence of denotata of any set of classes at any given point in time. Empirically, as well as logically, form varies continuously through time *and* space. Presumably this effect could be eliminated if one's samples came from the same location, that is, were superimposed, but in this special case, stratigraphy is the more elegant and parsimonious solution for a chronology. The spatial dimension of variation, no matter how small the amount of space, cannot be eliminated by restricting the groups to a particular locality.

Whereas the first two conditions that groups to be seriated must satisfy are concerned with the comparability of the groups, the third concerns the elimination of a dimension of variation. The first two conditions can be internally verified; the last condition is logically impossible to satisfy. Deetz and Dethlefsen point out that spatial variation may be identified, but this was possible in their case only because the groups used were already dated and their position in time relative to one another known. Importantly, then, space does affect the distributions used by seriation, and these effects cannot be segregated and eliminated. The third condition of application cannot be satisfied in the choice of groups to be seriated.

As it stands, then, seriation cannot be regarded as a method for chronological ordering, because it requires that spatial variation be eliminated in the units seriated, and this is impossible. This does not mean, however, that all seriations for previously undated groups are not chronologies. It simply means that none of them can be *demonstrated* to be a chronology because the basis for such inferences are lacking. Most seriations probably do represent at least gross chronologies, and some have in fact been demonstrated by independent means (e.g., radiocarbon dating), to be chronologies.

CONTROLLING SPATIAL VARIATION

The approach taken thus far has been to use the notion of "local area" as presented in the literature on seriation which focuses the attempt to control variation in form through space on the selection of groups to be included. So conceived the dilemma created by spatial variation for seriation is insoluble, except in the special case in which all the groups originate from the same point in space. This is probably the reason why the notion of "local area" has remained vague in the literature.

Deetz and Dethlefsen (1965) tender one means of controlling spatial variation without recourse to the notion of "local area." They note the similarity between rates of diffusion of ideas and the Doppler effect of sound waves and, on the basis of this analogy, propose that equations may be derived for rates of diffusion through space to eliminate skewing of seriations due to spatial variation (1965:200). Unfortunately, this is a trivial case. Their solution makes use of rates, and rates require absolute time control for computation. Once one has an absolute chronology sufficient for computing rates of diffusion, the construction of a seriation is pointless.

It has already been suggested that the insolubility of controlling spatial variation by the traditional approach of "local area" accrues from the fact that space as well as time is a coordinate or dimension along which form continuously varies. Thus it is in the construction of the classes used in a seriation which creates the form measured, and not solely in the selection of the groups, that the solution must lie. If the classes used are defined on the basis of attributes which show little variation in space and much variation in time, the classes so created will have distributions that are *primarily* the result of change through time and not change through space. All classes are biased by the selection of attributes for their definition from an infinite field of attributes that could have been distinguished and used for definition. Those classes which have been defined on the basis of attributes which show little variation in space and considerable variation in time provide, by means of this definitional bias, the basis for inferring that a given seriation is a chronology. This means that what must be involved in the definition of "temporal" or "stylistic" is not simply sensitivity to change through time, but a greater sensitivity to change through time than to change through space. If this is done, the need for the third and impossible condition for application of seriation is eliminated.

While "local area" need not be a general criterion for application of the method, it is, of course, not possible to eliminate spatial variation. It is only possible to reduce its distributional effects to a level of secondary importance. Nonetheless it is obvious that the size of the area from which the groups are drawn is important. The larger the area is, the fewer the classes that will meet the requirements of being an "historical" class. No absolute limits, nor even relative limits, can be set in terms of geographical space, for this will depend in part upon the number of groups seriated, their distribution in the segment of time considered, and the history of the various stylistic elements embodied in the classes. While there must be spatial variation in the various groups seriated, the problem is to discover whether or not such variation has been included in the seriation, and if it has, which groups' positions are affected by such variation, so that they may be removed from the "chronology."

There can be little doubt, if only because variation through time is unidirectional and thus more apt to produce non-random distributions, that most seriations convey some kind of gross chronology. In Figs. 1 and 2, for example, there would be little doubt that the uppermost and lowermost units were chronologically ordered relative to one another. There is, however, no way to judge whether two adjacent units in a seriation, even if statistically they can be shown to be significantly different from one another, are chronologically ordered. Spatial variation must be present in the data, and it remains to show whether or not or to what degree it is registered in the ordering. The effects of such variation will be much more apparent and of much more concern in frequency seriation which makes unique assignments than in occurrence seriation where the units are grouped into periods, although occurrence seriation is not immune to the effects of spatial variation.

There would appear to be a simple means of assessing how much of the order produced by a seriation can be regarded as chronological. If the investigator has biased his classes so that their distributions are primarily the result of temporal change, and he further has met all of the other stipulations of the seriation model and its application, it should be possible to control spatial variation by creating multiple seriations of the same set of groups using different sets of classes and extract as chronology only the ordering common to all of the seriations. If, for example, one has frequency-seriated ten groups in terms of projectile-point types, pottery types, scraper types, burial types, and house types, and each of the seriations orders the ten groups in precisely the same manner, the ordering can be presumed to be chronological, and such an inference is based on the temporal bias built into the classes used. This apparently is the kind of solution suggested but not explicated by Clarke (1968:427). If one unit in this example is ordered differently in the several seriations, it can be assumed that it is sufficiently close in time to the units with which it varies that the effects of spatial variation are as great as or greater than those of temporal variation. In this case, it would be possible to state that the classes used are insufficient to differentiate these units chronologically, and thus these units must be regarded as contemporary in all of the seriations, or deleted from them. An alternative would be to reformulate the classes used so that consistent orders would be produced by all seriations for all of the groups included in them. In fact, this situation makes it possible to define the elusive quality of "contemporaneity" so often encountered in the literature. Contemporaneity simply means that given a specified set of classes with which measurement is made, the units being compared are assigned ambiguous temporal positions, that is, they cannot be distinguished in temporal terms. This clearly is a function of the classes used in the comparison.

To account for the repetition of the identical order in several seriations of the same set of groups in terms of spatial variation, it would be necessary to make a set of assumptions about change which would be patently unlikely if not demonstrably false. In both the case explicated by Deetz and Dethlefsen (1965) and in my own work, the ultimate source of spatial variation is that some people accept some ideas more readily than others, and this makes change uneven through time and space. For repetitive patterning in multiple seriations of the same set of groups to be due to spatial variation, it would be necessary to demonstrate: 1) that the people responsible for each group were equally receptive to innovation in all of the sets of classes tested, and 2) that they were receptive or resistant to change in these classes to exactly the same degree. Unless both of these assumptions can be satisfied, ambiguous positions in different seriations would result and thus be identifiable as distinct from temporal change. The only conceivable situation in which these two conditions might even be approximated is the migration of a group of people along a single line (e.g., a river valley). Here spatial variation might approach the unidirectional nature of time, space and time becoming nearly coincident. Fortunately, this situation is of infrequent occurrence and usually easily recognized. Importantly, apart from this rather special case, conditions do not arise which would permit a confusion of spatial and temporal variation in multiple seriations.

SUMMARY

A seriation is not a chronology; chronologies are inferred from seriations. This discussion has focused upon the problem of why, and under what circumstances, seriations may be inferred to be chronologies. Not at issue are the various means of ordering, unilinear scaling in the case of seriation. For the anthropologist, archaeologist, or any professional other than a statistician, the means of scaling is an incidental although not unimportant matter. Any set of phenomena may be ordered, but what the order means is an inference based upon three things, none of which are statistical in nature: 1) the kinds of units employed in recording and measuring the phenomena, 2) an assumption or set of assumptions which link a particular kind of order to the problem being solved, and, 3) the characteristics of the phenomena which influence the problem being solved.

In the case of seriation, historical classes are used to record the phenomena and are the units of measurement. By historical class is meant a class which varies more in the dimension of time than it does in the dimension of space. Only by employing this kind of class as the means of recording and measurement is there any reason to infer that seriations yield chronological orders. The link between the formal order of a seriation and chronology is provided by a single assumption phrased as a model of continuous distribution if one is using occurrence seriation or as unimodal frequency distributions if one is using frequency seriation. The denotata of historical classes display continuous distributions through time, and the frequency of representation takes the form of a unimodal curve. Only those orders, with allowances made for sampling errors, which meet these specifications can be inferred to be chronologies. Finally, two characteristics of the groups of phenomena seriated enter into the problem of chronology, and these are stated as conditions of application. The groups must be of comparable duration, and they must be products of the same cultural tradition. As long as one does not accept as chronologies seriations which do not conform to the model posited by the assumptions, these conditions are trivial since the model will not be approximated unless they are met. The successful construction of a seriation constitutes an affirmative test of these conditions.

Seriations are designed to eliminate all sources of variation except variation in time so that the placement of the units is an accurate statement of relative age. Spatial variation cannot be eliminated, and this acts to skew the results so that a set of groups may be arranged to meet the specifications required by the method and the order still not be chronological in its entirety. To establish that an order produced by seriation is chronological, multiple seriations of the set of groups using different sets of historical classes is necessary. Only that order which is repetitive over the series of seriations may be regarded as chronological. Groups assigned ambiguous positions must be dropped from the seriation or regarded as contemporaneous.

Since the seriations published to date of undated material neither conform strictly to the requirements of the model nor do they explicitly control the dimension of space, the orders suggested by them cannot be demonstrated to be chronological. Insofar as seriations in the past do attempt to reduce variation to a single straight line, and since time is in general the only unidirectional axis of variation, there can be little doubt that all reasonably well executed seriations are grossly chronological and some may be so in detail.

Two main sources of error are generally involved. First, and characteristic of both the graphic techniques and the statistical presentations, has been the acceptance of the *best* order, the closest approximation to the model, rather than a particular order. The best order, however, need not be chronological. To be able to infer that a seriation is a chronology, that each of the groups included is chronologically ordered with respect to all other groups, requires that the only deviations from the model of continuous distribution and unimodal distributions of frequencies be accountable as sampling error. Any other deviation indicates the presence of non-temporal variation. Both the use of ad hoc typologies, which may be historical classes only in part if at all, and seriating groups which do not meet the conditions of application are the major contributors to this source of error. A common example, following the precedent of Ford (1949), is to include stratigraphically ordered collections as a "check" upon a seriation without ascertaining whether or not such collections can be appropriately ordered by seriation. In particular, the condition of comparable duration is often violated in this circumstance. The conditions that sets of phenomena must meet differ between the two methods. Not all units which can be ordered by stratigraphy can be

chronologically ordered by seriation any more than stratigraphy can order all collections that can be seriated. In eliminating this source of error, graphic presentations currently have certain advantages over statistical techniques in that the latter do not show the source of deviation or "stress." Some kinds of stress, namely those due to sampling error, are tolerable. Other kinds are not. The information contained in a matrix of similarity coefficients is not sufficient to separate sources of deviation.

The second source of error in published seriations lies in the lack of explicit control of spatial variation. Single seriations and not orders that are repeated in multiple seriations are usually interpreted as chronologies. In these cases, how much of the order is chronological and how much is not is problematical.

A seriation may be inferred to be a chronology when: 1) the classes used are historical, 2) the groups seriated are of comparable duration, 3) the groups seriated are drawn from the same cultural tradition, and 4) when the only deviation from the models of continuous distribution and unimodal frequency representation are accountable as sampling error. When these conditions are not met, the seriation cannot be inferred to be chronology and this is true no matter how the ordering was achieved or whether or not it is replicable. Non-chronological orderings are just as replicable as chronological ones, for all that is required is consistency. These conditions are not, in a pragmatic sense, difficult to meet, but it is probable that seriation is not as widely applicable as its past use would indicate.

BRAINERD, GEORGE W.
1951 The place of chronological ordering in archaeological analysis. *American Antiquity* 16:301-313.

BROWN, J. A., and L. C. FREEMAN, JR.
1964 A UNIVAC analysis of sherd frequencies from the Carter Ranch Pueblo, Eastern Arizona. *American Antiquity* 30:162-167.

CLARKE, DAVID L.
1968 *Analytical archaeology*. Metheun and Co., Ltd.

CONKLIN, HAROLD C.
1964 Ethnogenealogical method. In *Explorations in cultural anthropology*, edited by Ward H. Goodenough, pp. 25-55. McGraw-Hill.

COWGILL, GEORGE L.
1968a Review of Hole and Shaw "Computer analysis of chronological seriation." *American Antiquity* 33:517-519.
1968b Archaeological applications of factor, cluster, and proximity analysis. *American Antiquity* 33:367-375.

CRAYTOR, WILLIAM B., and LEROY JOHNSON, JR.
1968 Refinements in computerized item seriation. *Museum of Natural History, University of Oregon, Bulletin* 10.

DEETZ, JAMES, and EDWIN DETHLEFSEN
1965 The Doppler effect and archaeology: a consideration of the spatial aspects of seriation. *Southwestern Journal of Anthropology* 21:196-206.

DEMPSEY, PAUL, and MARTIN BAUMHOFF
1963 The statistical use of artifact distributions to establish chronological sequences. *American Antiquity* 28:496-509.

DUNNELL, ROBERT C.
1967 The prehistory of Fishtrap, Kentucky: archaeological interpretation in marginal areas. MS, doctoral dissertation, Yale University.

FORD, JAMES A.
1949 Cultural dating of prehistoric sites in Viru Valley, Peru. In Surface survey of the Viru Valley, Peru. *American Museum of Natural History, Anthropological Papers* 43:31-78.

HANSON, LEE H., R. C. DUNNELL and D. L. HARDESTY
1964 *The Slone Site, Pike County, Kentucky* (Contract 14-10-0131-1130). National Park Service, Southeastern Region: Richmond. (Mimeo.)

HOLE, FRANK and MARY SHAW
1967 Computer analysis of chronological seriation. *Rice University Studies* 53.

JOHNSON, LEROY JR.
1968 Item seriation as an aid for elementary scale and cluster analysis. *Museum of Natural History, University of Oregon, Bulletin* 15.

KUZARA, R. S., F. R. MEAD and K. A. DIXON
1966 Seriation of anthropological data: a computer program for matrix ordering. *American Anthropologist* 68:1442-55.

LIPE, WILLIAM D.
1964 Comments on Dempsey and Baumhoff "The statistical use of artifact distributions to establish chronological sequence." *American Antiquity* 30:103-4.

LOUNSBURY, FLOYD G.
1964 The structural analysis of kinship semantics. In *The Proceedings of the Ninth International Congress of Linguists*, edited by Horace G. Lunt, pp. 1073-93. Mouton and Co.

MAYER-OAKES, WILLIAM J.
1955 Prehistory of the upper Ohio Valley. *Annals of the Carnegie Museum, Pittsburgh, Anthropological Series*, No. 2.

MEIGHAN, CLEMENT W.
1959 A new method for the seriation of archaeological collections. *American Antiquity* 25:203-211.

MORRIS, CHARLES W.
1938 Foundations of the theory of signs. *Foundations of the unity of science* 1. University of Chicago Press.
PHILLIPS, PHILIP, J. A. FORD and J. B. GRIFFIN
1951 Archaeological survey in the lower Mississippi Alluvial Valley, 1940-47. *Papers of the Peabody Museum of American Archaeology and Ethnology, Harvard University,* Vol. 25.
ROBINSON, W. S.
1951 A method for chronologically ordering archaeological deposits. *American Antiquity* 16:293-301.
ROUSE, IRVING B.
1939 Prehistory in Haiti, a study in method. *Yale University Publications in Anthropology*, No. 21.
1967 Seriation in archaeology. In *American historical anthropology*, edited by Carroll L. Riley and W. W. Taylor, pp. 153-95. Southern Illinois University Press.
ROWE, JOHN H.
1961 Stratigraphy and seriation. *American Antiquity* 25:324-330.
SPAULDING, ALBERT C.
1960 The dimensions of archaeology. In *Essays in the science of culture in honor of Leslie A. White*, edited by Gertrude E. Dole and Robert L. Carneiro, pp. 437-56. Thomas Y. Crowell and Co.