CERAMIC MICRO-SERIATION: TYPES OR ATTRIBUTES?

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Micro-seriation using attributes of decorated ceramics has been shown to accurately refine intrasite and intersite relative dating. Using data from Pueblo de los Muertos, a nucleated town in west-central New Mexico, this presentation demonstrates that micro-seriation of type frequencies produces equally accurate results. Typological analysis also provides substantial time savings when compared to attribute recording. Additionally, using types with established temporal ranges permits linkage of relative seriation with absolute dates. A combination of correspondence analysis and k-means cluster analysis was found to provide sound and easily interpretable results. The results of a typological seriation of Pueblo de los Muertos deposits are examined, and the utility of typological seriation for other contexts is considered.

La micro-seriacion de atributos de decoracion ceramica ha sido considerada como la tecnica acertada para refinar las fechas relativas dentro de un sitio y entre varios sitios. Este articulo utiliza datos de Pueblo de los Muertos, un pueblo nucleado localizado en el centro-oeste de Nuevo Mexico, para demostrar que la micro-seriacion de frecuencia de tipos ceramicos produce resultados igualmente acertados. El analisis tipologico tambien representa un ahorro de tiempo substancial en comparacion con el tiempo que se necesita para analizar los atributos decorativos. Además, el uso de tipos con rangos temporales establecidos permite enlazar la seriacion relativa con fechamientos absolutos. Una combinacion entre Analisis de Correspondencia y el metodo de agrupamiento con k-medias produjo resultados confiables y fáciles de interpretar. Aqui se examinan los resultados de una seriacion tipologica de los depositos de Pueblo de los Muertos y se considera la utilidad de la seriacion tipologica en otros contextos.

This analysis has three objectives: to present techniques valuable in the seriation of archaeological data; to evaluate the utility of type frequency seriation relative to attribute-based seriation (LeBlanc 1975); and to examine the nature of the occupation and abandonment of Pueblo de los Muertos, a nucleated town site in west-central New Mexico investigated by the Cibola Archaeological Research Project.

This presentation begins with an overview of seriation techniques, and presents an approach that couples correspondence analysis with k-means cluster analysis. A brief introduction to the Cibola project is followed by description and examination of data from Pueblo de Los Muertos, and comparison of typological seriation results to attribute seriation performed on many of the same units by LeBlanc (1975) in his pioneering article on micro-seriation. This provides a basis for comparative evaluation of techniques and procedures useful for micro-seriation, and reveals that type frequencies produce equally accurate results. The value of intrasite seriation is considered relative to its ability to provide insights into the occupation of Pueblo de los Muertos (LA 1585).

Seriation Techniques

Seriation is the process of ordering a number of observations relative to some dimension of variability (Spaulding 1978:27). In archaeology, the relevant dimension is often time, but any number of dimensions can be seriated. A detailed consideration of the theoretical underpinnings of seriation is not warranted here (see Cowgill 1972; Dunnell 1970; Marquardt 1978; Rouse 1967), but a number of critical aspects require discussion.
Central to any chronological seriation is selection of appropriate units of observation. It is also necessary to recognize that interpretation is independent of the ordering procedure (Dunnell 1970; Johnson 1972; Marquardt 1978; Rouse 1967).

A variety of techniques for the ordering of archaeological data have been employed. Occurrence data (presence/absence) and matrix reordering often produce satisfactory chronological ordering given small assemblages and a limited number of artifact categories. More popular techniques for seriating numerous archaeological cases (sites, features, or deposits) include cluster analysis approaches (Matson and True 1974), and a variety of multivariate scaling techniques, principally variants of multidimensional scaling (MDS) (Cowgill 1968, 1972; Matson and True 1974; True and Matson 1970; Washburn and Matson 1985). The benefit of combining scaling and clustering techniques has also been noted (Djindjian 1985, 1988; Johnson 1972).

The approach taken here is to combine correspondence analysis (CA), a multivariate scaling procedure, and k-means cluster analysis, using the patterning derived from each to evaluate consistent patterning in the original data (Cowgill 1968). Because of its advantages, I have opted to use a data analysis and display technique (CA) not well established in Americanist literature, but which is widely used in Europe for seriation and other applications. I anticipate that this paper will contribute to a wider appreciation of the possibilities of CA.

CA is a technique for data reduction and display similar, in many respects, to principal components analysis (PCA) and MDS (Hill 1974; Ringrose 1992:615). However, it works directly on counts and its strength as a display technique is the simultaneous projection of both cases and variables in the same spatial dimensions. In a sense, this helps one interpret the relative contribution of each variable to the dimensional representation (Bolviken et al. 1982:43). CA has been widely used in Europe and has proven useful for seriation (Bolviken et al. 1982; Djindjian 1985, 1989; Hodson and Tyers 1988; Ihm 1987; Laxton and Restorick 1989; Lerdele 1985; Madsen 1988, 1989; Madsen, ed., 1988; Slachmuylder 1985). Awareness of CA is increasing as it becomes incorporated into widely used computer statistical packages.

K-means cluster analysis (Doran and Hodson 1975:180–184; Kintigh and Ammerman 1982) is a nonhierarchical clustering procedure for grouping cases. One distinct advantage of this technique is that it provides information about clusters in terms of the input data. If the input data consist of percentages of different ceramic types, k-means clusters are described by the mean and standard deviation (in percentages) of the pottery types composing each cluster (this information can be calculated for clusters created by any clustering algorithm). This differs from other multivariate techniques such as MDS, CA, PCA, and factor analysis where one gets a series of “scores” or “loadings” that cannot be so directly related to input data. Cluster characterization data presents the opportunity of calculating mean ceramic dates (e.g., South 1978) for each cluster. This can provide approximate absolute dates to portions of a multivariate display.

The Database

The data used in this analysis derive from the Cibola Archaeological Research Project, a two-year survey and excavation project conducted in the El Morro Valley of west-central New Mexico (LeBlanc 1978; Watson et al. 1980). The Zuni (Cibola) region, and the El Morro Valley in particular, contains dense occupation between A.D. 1250 and A.D. 1450 in two different settlement types. The pre–A.D. 1275 pattern consists of spatially dispersed multiple-room block settlements that appear to interact as a community (LeBlanc 1978). The post–A.D. 1275 sites are planned, rapidly constructed, nucleated towns with 200 to 1,400 rooms that were occupied for only a few generations (Kintigh 1985a).

The Zuni region has a well-developed decorated ceramic chronology that permits accurate assignment of occupation ranges, usually to within 50 years, based on ceramic groups (Colton 1953:65; Kintigh 1985a). Fine-grained seriation, or micro-seriation (LeBlanc 1975; Marquardt 1974) using ceramic attributes, has been used to show relative temporal intersite and intrasite relationships. In order to make temporal discriminations within periods defined by ceramic groups, Marquardt (1974) and LeBlanc (1975) focused on ceramic attributes thought to be temporally sensi-
They employed factor analysis and MDS, respectively, in their seriations. LeBlanc used physical attributes of ceramics (e.g., Munsell color, slip color) and other variables, such as jar:bowl ratios in his study (1975:26–27, Table 3). His units derived from Pueblo de Los Muertos and Scribe S, two sites that were the focus of Cibola project excavation efforts (LeBlanc 1978). Marquardt employed attribute ratios (1974:97, 100, Table 3-8), stressing the need for logically independent variables (1978:304). Marquardt (1974) was more concerned with intersite chronology, and demonstrated the contemporaneity of deposits from a number of the nucleated pueblos (ca. A.D. 1275–1400) in the El Morro Valley. Both sought to avoid pitfalls associated with intersite chronology, and demonstrated the contemporaneity of deposits from a number of the nucleated pueblos (ca. A.D. 1275–1400) in the El Morro Valley.

The argument against using typological data is in need of reevaluation. The primary reasons cited for rejecting typological data are that small pieces frequently cannot be assigned to type, resulting in loss of information (LeBlanc 1975), that type identification is too subjective and variable from person-to-person (Plog 1983:136; Washburn 1983; Washburn and Matson 1985:75–76), that types were originally created to systematize (normative) time-space relationships, and that types obscure or homogenize variability (Redman 1977:46, 1978:187; Watson 1977:387).

The lack of an adequate number of sherds assignable to type is generally not a problem. In fact, many of the ceramic attributes recorded by the Cibola project (Redman 1978) seem to require a sherd that is probably large enough to assign to type. Typological assignment is much faster than recording a number of attributes for each sherd, as is creating the resultant database. There are subjective elements involved for attribute or type recording. Types represent associations of "recurring attributes." Whether these are statistically significant or not is less relevant (Cowgill 1972:386; Rouse 1967:166–167; Spaulding 1978:29–30). The fact that types were specifically designed to help order observations along a chronological dimension (Dunnell 1970:308; Watson 1977) often makes them appropriate for temporal seriation. Types are constellations of attributes, many of which are individually isolable, some of which vary with time, while others may not (e.g., Plog 1983:132–133). Recording attributes individually may isolate which attributes are time sensitive. If we grant this, then, at an intuitive level, it is apparent that types created for time-space systematics should represent constellations of potentially trend-sensitive attributes. The question then becomes: Does the homogenizing effect of typological analysis diminish trend-sensitive information to the extent that it is incapable of informing upon fine-grained temporal variation?

Given a situation where a number of reasonably well-dated ceramic types occur in varying frequencies within excavated assemblages from a single site, the potential for capturing temporal variation of attributes via typological frequency analysis appears likely. Cowgill (1972) has noted that loss of some information may actually be desirable for seriation. I sought to determine if analysis of type frequencies alone could reproduce the results of the more detailed seriation work successfully conducted by Marquardt (1974) and LeBlanc (1975). If so, I hoped to identify the advantages and limitations of a type-based approach. The data used in this analysis come from Pueblo de Los Muertos, a nucleated town in the El Morro Valley that was one focus of Cibola project excavations. The site provides an ideal test case because the attribute seriation is well known and readily accessible (LeBlanc 1975).

Decorated ceramics from the Cibola project were originally tabulated using a detailed attribute coding system (Redman 1977). The data discussed and analyzed here consist of decorated ceramic type counts from Pueblo de los Muertos. The sherds were tabulated by Watson and Kintigh. Although other types are present, only counts of the following decorated ceramic types were utilized: Tularosa Black-on-White, St. Johns Polychrome, Springerville Polychrome, Pinedale Polychrome, Kwakina Polychrome, and Heshotauthla Polychrome. Other ceramic types are comparatively rare, providing little additional temporal information. Approximate date ranges for these ceramics and the relative order of their appearance are presented in Figure 1. Carlson (1970) presents detailed descriptions and photographs of these types except for Tularosa Black-
Figure 1. Approximate date ranges for Zuni-area decorated ceramic types used in this analysis.

on-White. Tularosa Black-on-White occurs primarily in jar form, and can be considered an approximate design equivalent of St. Johns Polychrome.

Typological information was not recorded during the original coding, so I have only used collections that have since been typologically analyzed. All ceramics were shaken through ¼-inch mesh, with typological assignment attempted for all pieces larger than ½ inch (¼-inch mesh was used for excavation). Sherds not identifiable to type were tabulated as such. The most problematic typological distinctions are between St. Johns Polychrome and Heshotauthla Polychrome, bowls characterized by a gradient from thick-to-thin exterior white lines and from matte-to-subglaze-to-glaze interior paint dating A.D. 1275–1300. Because only two persons, often working together, typed all of the sherds, consistent biases related to individual differences in typological assignment should be reduced (e.g., Plog 1978:159, 1983:136).

The data consist of counts from multiple proveniences and several excavated levels. Occasionally, adjacent levels or entire units with small sample sizes or only excavated for a few levels were combined. Table 1 presents ceramic counts by type for all of the proveniences used in this analysis, with a column specifying comparable levels used by LeBlanc (1975). For the k-means analyses presented here, ceramic type counts have been converted to (row) percentages to minimize the effect of sample size (Cowgill 1968:372). I have employed a k-means program written by Kintigh (Kintigh and Ammerman 1982). The CA analysis was performed on counts using the Multi-Variate Statistical Package written by Kovach. Each of these procedures can be found in more widely available statistical packages.

Analysis of Cibola Type Frequency Data
Several analyses were conducted to ascertain the degree to which relative seriation based on type frequencies (and/or percentages) could aid in archaeological interpretation. Initially, units were simply aggregated into upper and lower levels from each provenience. This provides information about general relationships among units and can produce a well-ordered seriation. However, analysis of individual levels or small aggregates of levels was thought to more accurately reflect the complex relationships inherent in these archaeological deposits.

Attribute and Type Seriation
Correspondence analysis and k-means both isolate the same axes of variability within Pueblo de los Muertos assemblages. A plot of the first two CA axes (Figure 2) shows the relative contributions of the various types. Individual cases (levels) are plotted with symbols representing the k-means six cluster solution. K-means groups together excavated levels containing similar percentages of decorated types. This demonstrates that both techniques arrange cases in similar manner. Axis 1 accounts for 70 percent of the variance, and can be interpreted as time. Axis 1 places St. Johns Polychrome and Tularosa Black-on-White, the earlier types, and earlier units to the left, with later types and units to the right. The second axis, accounting for 16 percent of the variance, captures
have longer use-lives than decorated bowls (see LeBlanc 1975:28).

Tularosa Black-on-White appears to persist in the record between Tularosa Black-on-White and all other differences. The primary distinction on Axis 2 is a combination of functional and possibly temporal differences. The primary distinction on Axis 2 is between Tularosa Black-on-White and all other types, and Tularosa Black-on-White is the only type that occurs primarily in jar form. Tularosa Black-on-White appears to persist in the record slightly later than St. Johns Polychrome (its temporal equivalent), probably because decorated jars have longer use-lives than decorated bowls (see LeBlanc 1975:28).

Examine the data, then comparing these results with LeBlanc’s MDS (1975:Figure 7) on a case-by-case basis, requires the plotting of CA cases in a single dimension using Axis 1. There is a mild arch, or “horseshoe,” detectable in the CA plot. The arch begins at the lower left, rises toward the center, and tapers off to the lower right. Plotting points that are curvilinear in a single dimension alters, somewhat, the relationship among points. However, that the “horseshoe” is
relatively weak in this data set (a function of the large proportion of variance captured by the first axis relative to the second) reduces this distortion.

Comparing the order of common units indicates agreement between LeBlanc’s MDS and CA. Table 2 presents a rank-ordering of common units. The CA units are ordered using the first axis, and LeBlanc’s are ordered by MDS (1975:Figure 7). There are 13 units common to both analyses (refer to Table 1). Many are similarly ordered, especially the earlier units. Two

Table 2. Rank-Order Association.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Level(s)</th>
<th>CA</th>
<th>MDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>108</td>
<td></td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>500</td>
<td></td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>419</td>
<td></td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>19</td>
<td>6 &amp; 7</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>303</td>
<td>11 &amp; 12</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>419</td>
<td>4 &amp; 5</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>105</td>
<td></td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>108</td>
<td></td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>20</td>
<td>5 &amp; 6</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>419</td>
<td>1 &amp; 2</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>108</td>
<td></td>
<td>8</td>
<td>13</td>
</tr>
</tbody>
</table>

Late

CA = correspondence analysis, MDS = multidimensional scaling. Spearman’s $r_s = .956$, Kendall’s $\tau = .885$

Note: MDS data from LeBlanc 1975: Figure 7.

rank-order measures of association were calculated, and both (Spearman’s $r_s = .956$, Kendall’s $\tau = .885$) indicate a very strong positive association. Both measures vary from -1.0 to 1.0, with 1.0 indicating a perfect positive relationship. The substantial agreement between these analyses suggests that approximately equivalent results can be obtained through the use of typological data.

Returning to interpretation of the CA plot, it is difficult to objectively interpret points along a nonlinear continuum, such as those produced by CA or MDS. However, the graphical presentation is extremely helpful for visualizing relationships of cases to variables (types). K-means can more formally characterize these relationships by providing information directly referable to input data. Table 3 presents the cluster characterization values for the six-cluster solution seen plotted in Figure 2, including the mean and standard deviation of type frequencies and cases assigned to each cluster. In addition to illustrating that patterning is not a spurious result of the CA technique, the k-means cluster characterization information can be used to assign probable absolute dates to portions of the CA plot using the mean ceramic date (MCD) formula (South 1978).

Multiplying the mean percentage of each ceramic type by the midpoint of their temporal range (Figure 1), and then dividing this by the
Table 3. K-means Solution Information.

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Unit/Level(s)</th>
<th>MCD</th>
<th>Tularosa</th>
<th>St. Johns</th>
<th>Springerville</th>
<th>Pinedale</th>
<th>Kwakina</th>
<th>Heshotauthla</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20/9, 104/4, 105/4 &amp; 5, 225/6, 225/7, 419/6, 419/7, 500/2, 4733/3 &amp; 4, 4915/2</td>
<td>A.D. 1283</td>
<td>11.5/3.3</td>
<td>74.5/7.0</td>
<td>1.3/1.3</td>
<td>.5/1.0</td>
<td>8.4/3.5</td>
<td>3.8/2.9</td>
</tr>
<tr>
<td>2</td>
<td>19/6 &amp; 7, 20/10 &amp; 11, 105/7, 108/7, 303/11 &amp; 12, 502/2, 502/3</td>
<td>A.D. 1283</td>
<td>32.8/5.3</td>
<td>54.1/5.2</td>
<td>1.1/1.4</td>
<td>.2/.6</td>
<td>9.1/4.6</td>
<td>3.1/3.0</td>
</tr>
<tr>
<td>3</td>
<td>19/1 &amp; 2, 105/2, 108/5, 303/5, 500/1</td>
<td>A.D. 1295</td>
<td>26.9/7.5</td>
<td>39.9/7.0</td>
<td>3.6/2.2</td>
<td>1.0/1.8</td>
<td>13.1/4.5</td>
<td>15.5/2.0</td>
</tr>
<tr>
<td>4</td>
<td>20/7 &amp; 8, 300/all, 419/4 &amp; 5, 4612/2</td>
<td>A.D. 1294</td>
<td>13.7/8.0</td>
<td>55.7/4.8</td>
<td>2.9/1.3</td>
<td>1.5/2</td>
<td>5.1/2.5</td>
<td>21.1/6.0</td>
</tr>
<tr>
<td>5</td>
<td>19/5, 20/1 &amp; 2, 20/3 &amp; 4, 108/1, 225/2 &amp; 3, 419/3, 4612/1</td>
<td>A.D. 1308</td>
<td>11.3/5.6</td>
<td>34.3/6.0</td>
<td>4.9/2.8</td>
<td>3.6/3.9</td>
<td>17.2/6.3</td>
<td>28.7/3.7</td>
</tr>
<tr>
<td>6</td>
<td>20/5 &amp; 6, 108/2, 108/3, 108/4, 410/all, 418/all, 410/1 &amp; 2</td>
<td>A.D. 1321</td>
<td>13.0/5.6</td>
<td>16.8/4.5</td>
<td>3.1/1.7</td>
<td>3.7/1.6</td>
<td>19.3/6.1</td>
<td>43.1/7.2</td>
</tr>
</tbody>
</table>

Note: Ceramic types represented are Tularosa Black-on-White, St. Johns Polychrome, Springerville Polychrome, Pinedale Polychrome, Kwakina Polychrome, and Heshotauthla Polychrome. Mean ceramic date (MCD), type percentage mean/standard deviation, and cases are presented by cluster.

sum of the mean percentages, produces an MCD for each cluster (South 1978). For the calculations used here, I have employed a midpoint date of A.D. 1275 for Tularosa Black-on-White and St. Johns Polychrome because the cutting dates for the earlier occupation of the site immediately adjacent to Pueblo de los Muertos (Scribe S) suggest the majority of the earlier construction post-dates A.D. 1250 (Watson et al. 1980:205). The purpose of using South’s formula here is to demonstrate the value of k-means cluster characterization in seriation. MCDs for each cluster are also listed in Table 3. The MCDs for clusters 1 and 2, and 3 and 4 are nearly identical. This suggests that while these clusters (1 and 2, 3 and 4, respectively) may be characterized by different types, they are temporally equivalent. The cases in these clusters, respectively, occupy the same portions of Axis 1 in the CA plot (Figure 2), supporting the inference of this axis as primarily representing time.

The MCD formula produces dates that are remarkably consistent with other information known from Pueblo de los Muertos (see following). This demonstrates the utility of k-means cluster data. Although Christenson (1994) has recently demonstrated that MCD can provide results as accurate as other chronometric techniques, significant concern about the approach persists. Refinements in the MCD approach that produce date ranges rather than mean dates (e.g., Steponaitis and Kintigh 1992), and in the dating of ceramics it is applied to, should yield more reliable absolute date referents.

Occupation and Abandonment of Pueblo de los Muertos

LeBlanc (1975) did not engage in specific interpretation of his seriation data; an attempt to do so is made here because our ability to “micro-seriate” deposits is meaningless unless it can provide otherwise unrealized insights. The construction sequence of Pueblo de los Muertos is relatively well documented based on extensive wall trenching (Marquardt 1974:37, 39; Watson et al. 1980). Initially, two rows of rooms were constructed in a large square (Figure 3), with another interior tier then added. Watson et al. (1980:207) suggest the site was not occupied until this was completed. Dendrochronological dates suggest initial construction at about A.D. 1285. The MCDs for clusters 1 and 2 agree with this date. Somewhat later, a fourth
bank of rooms was added to the interior, constructed atop a light accumulation of plaza trash.

Given the limited number of rooms actually excavated (13) relative to an estimated total of 500 to 850 rooms (Kintigh 1985a:50–51; Marquardt 1974:43; Watson et al. 1980:207), it is difficult to extrapolate anything more than a suggestive sequence of occupation. We must also keep in mind that we are witnessing the abandonment of rooms evidenced by their filling with trash. Most rooms contain at least one hearth and appear to have been used for habitation (Marquardt 1974:Table 2-2). Rooms 303 and 418 represent kiva locations, although 418 is a converted habitation room (Marquardt 1974:43, 45; Watson et al. 1980:207). Provenience 419, originally thought to have been a room, turned out to be an access corridor through the west wall (Watson et al. 1980:207).

A schematic presentation of the temporal relationships between units and levels is presented as Figure 4. The earliest trash deposition includes the lower levels of nearly all of the rooms excavated. The lower levels of rooms 20, 104, 105, 108, 225, 500 and 502, and trench deposits 4733 and 4915 date to the earliest period of deposition. Marquardt’s (1974:40) suggestion that Pueblo de los Muertos was constructed around another contemporaneously occupied pueblo is potentially supported by the similarity of the room 500 and 502 deposits to those within rooms of Pueblo de los Muertos proper. The potential access corridor, designated 419, appears to have accumulated trash throughout the occupation.

Several of these rooms appear to continue to accumulate trash for the remainder of the site’s occupation, suggesting they were abandoned early within Pueblo de los Muertos’s life history. Rooms 19, 300, and 303 appear to begin being trash filled toward the middle of the occupation range, while rooms 108 and 225 both might have been built atop early trash accumulations and occupied until relatively late. Room 303, an abnormally large room with a flagstone-lined floor and a sipapu (a hole in the floor that represents the place of emergence from the underworld) (Marquardt 1974:43), apparently fell out of use rapidly.

The dominance of units with early trash deposition corroborates the interpretation of a relatively short, but intensive occupation at Pueblo de los Muertos. From the limited excavation sample, it appears that many rooms were occupied very briefly, then became convenient refuse disposal locations. Spatially, the rooms in the northern portion of the site appear to have declined earliest. After some initial trash deposition, room 108 appears to have been occupied until relatively
late. The filling of adjacent rooms (104 and 105) with trash indicates that rooms in this vicinity continued to be occupied. The early deposits from these northern rooms have a somewhat greater association with Tularosa Black-on-White dominated assemblages, possibly suggesting capture of a functional emphasis related to decorated jars. However, this association varies through time between levels of the same unit.

The remainder of the excavated rooms appear to be rapidly abandoned and filled with trash during the middle of the occupation. This may correspond with an early A.D. 1300s decline posited by LeBlanc (1978). This pattern incorporates the bulk of the site, with evidence for continued occupation strongest for units along the west. Rooms 410 and 418 contain shallow deposits and are among the latest deposits at the site. Room 418 was converted to a kiva from a habitation room (Marquardt 1974:43, 45; Watson et al. 1980:207), and may have been in use until final abandonment. The entry corridor and room 108 both contain late deposits, but room 108 deposits accumulated relatively rapidly. The western section of the pueblo might have been among the latest abandoned due to its proximity to the entrance/exit and Muerto Creek (Watson et al. 1980).

CA stratigraphically misplaces a few levels when projected onto a single dimension (Figure 4). These cases are highlighted and deserve comment. Levels 4 and 5, and 7 in Room 105 are reversed. These levels are assigned to clusters 1 and 2, which the MCD suggests are essentially contemporaneous. Levels 1 and 2 in Room 19, levels 5 and 6 in Room 20, and level 1 in Room 108 appear to be cases anomalous relative to the remainder of the levels from the same unit. The surface level misplacements may be related to post-depositional factors such as increased sherd breakage due to trampling, altering the relative contribution of some types. One could selectively remove troublesome levels to achieve a perfect
Seriation; however, stratigraphic misplacements may be instructive. To determine if local overrepresentation (e.g., several sherds from a single vessel), disturbance, or other factors may be responsible requires additional scrutiny.

That the bulk of the site was apparently constructed and abandoned rapidly has already been suggested (LeBlanc 1978; Watson et al. 1980). The typological seriation results confirm these suggestions, but also indicates relatively late use and trash-filling of some units at Pueblo de los Muertos. It appears that much of the site fell out of use rapidly and perhaps was never completely utilized. There was probably a greatly reduced presence at the site of somewhat greater duration than initially thought. The latest MCD is A.D. 1321 (Cluster 6). A limited number of later decorated types (e.g., Pinnawa Glaze-on-White) suggest that occupation may have persisted until about A.D. 1350. Additional investigation at Pueblo de los Muertos should concentrate on the northeastern and west-central portions of the site in order to determine the degree of post A.D. 1310–1320 occupation.

**Summary and Conclusions**

This presentation has demonstrated that it is possible to achieve accurate, fine-grained temporal seriation using type frequencies. The type frequency data from Pueblo de los Muertos are consistent with the relative seriation of units achieved by LeBlanc's (1975) intrasite attribute seriation. Although I have not presented information here, typological seriation of excavated collections from several El Morro Valley towns produces results comparable to those achieved by Marquardt (1974), who also employed attribute seriation.

I should like to point out that although Pueblo de los Muertos was occupied for a relatively short period (ca. 60 years), and that most of the ceramic types have relatively short durations, “micro-seriation” is equally relevant to most archaeological situations. Marquardt (1978:284) has stressed that micro-seriation is simply seriation in which the temporal resolution achieved is fine. I suggest that typological seriation employing the combination of techniques outlined above should be equally valuable in regions where ceramic types span several hundred years. Provided there is temporal variation in their frequencies, the only difference will be in the temporal resolution.

The combination of k-means and CA techniques has the potential to produce an extremely useful approach to seriation. CA is quantitatively robust and visually informative, and provides information about which variables account for the greatest amount of variance within a group of assemblages (as do factor and principal components analyses). Combining this with k-means clustering produces case groupings that are not always visually distinct. The properties of these clusters are directly referable to the original data, and the MCD formula was used to highlight the potential of relating dimensional representations with absolute dates. Refinements to the MCD approach and in the dating of the decorated ceramic types employed can only increase the precision of this approach. CA has many uses outside of seriation. It is especially useful as an exploratory procedure, allowing one to readily (and visually) assess major axes of variation in almost any data set.

Typological data may not always be appropriate for seriation problems. If only one or two ceramic types are present, or types are defined by attributes that do not vary with time (e.g., function or rim form), attribute-based analyses are clearly warranted. However, it is often unclear which attributes should be recorded, and what they will inform upon. A frequent approach is to record information on several attributes expecting that some will contain temporal information. CA may be particularly helpful in this case. CA can isolate axes of variability, and the display of the attributes along with cases can help isolate which are temporally sensitive. Performing this analysis on a subset of the overall assemblage would permit substantial time savings, as one could concentrate on coding only time-sensitive attributes for the remainder of the assemblage.

The success of seriating type frequencies is worthy of note. The coding of several attributes involves a substantially greater time investment (Christenson 1994:300), and this analysis suggests the results (for seriation) are no more useful than type data. Typological totals (and/or percentages) are the standard reporting technique for most published analyses and contract archaeology
reports. Type-based analysis of large assemblages is more feasible than detailed attribute coding in most instances. In general, I suggest that it would be preferable to type all (or a substantial percentage) of the sherds in a large collection rather than record attributes on a much smaller subsample. This approach has proven effective for intrasite analyses where the occupation spans about two generations, but may be even more useful for regional seriation of sites. K-means and CA should be able to refine within-period distinctions from systematic survey data. The use of types for refined dating may increase our ability to address issues of contemporaneity among sites and engage questions beyond temporal relationships.

Acknowledgments. I thank Patty Jo Watson for permitting me to work with these data, and Keith Kintigh for providing them on disk. The comments of Michael Graves, Keith Kintigh, R. G. Matson, and three anonymous reviewers have made this presentation more effective. Any remaining faults are the author's responsibility. I thank Maria Nieves Zedeño and Oralia Cabrera for translating the abstract and Shearon Vaughn for drafting the figures. The Cibola Archaeological Research Project fieldwork was supported by a grant from the National Science Foundation (GS-32987).

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Notes
1. Correspondence analysis applications and literature are expanding rapidly, but relatively clear descriptions can be found in Blankholm (1990), Bolviken et al. (1982), Madsen (1988), Van de Geer (1993a, 1993b), and Weller and Romney (1990). More detailed mathematical presentations (in English) are available in Gifi (1990), Greenacre (1984), Hill (1974) and Ringrose (1992).
3. The k-means program used here is part of Tools for Quantitative Archaeology, a software package available for purchase from Keith Kintigh, 2014 East Alameda Drive, Tempe, AZ 85282-4002, USA. The correspondence analysis was performed using the Multi-Variate Statistical Package, with shareware and commercial releases available from Warren Kovach, Kovach Computing Services, 85 Nant-y-Felin, Pentraeth, Anglesey LL75 8UY, Wales, UK.

Received June 7, 1994; accepted October 24, 1995.