328.

NUMERICAL ANALYSIS OF A PALUS BURIAL SITE

A Thesis

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ABSTRACT

Historic burials of the Palus offer a good check for recent numerical methods of seriation and clustering using similarity matrices. A wide assortment of trade beads and dated artifacts provides controls that can be contrasted against the results of seriation or clustering. Previously, similar classifications using similarity matrices depended upon traditional classification done by experts specialized in the specific field of the classification. With the addition of datable, historic artifacts these methods of classification can be more easily refined and criticized. This paper will explain the numerical methods used and will describe the classification patterns as suggested by datable, historic artifacts.

Weighted Pair-Group Method

The principles of the Weighted Pair-Group method are discussed in Chapter III. Edmund E. Tylutki, a mycologist at the University of Idaho, provided the program for the weighted pair-group method routine. Tylutki's program was created for clustering the ten-complement of the distance coefficient and for the clustering of correlation coefficients. Both routines were available with the 0.03 criterion or without. The ten-complement of the distance coefficient is linearly related to similarity as is the coefficient of Jaccard. The clustering routine for the ten-complement, as a result, was used for the coefficient of Jaccard. The coefficient of Jaccard was multiplied by ten to put it in the same range as most ten-complements of distance coefficients. For the WPGM used on the burials, the 0.03 criterion was excluded. In each case, the results were identical.

Exactly the same thirty burials seriated by the Program Seriate were clustered by the WPGM borrowed from Tylutki.

The resulting dendrogram is included in Fig. 12.

R-Technique Ogives

Noting that burials 69, 224, 26, 151, and 209 all formed a strong cluster, an ogive was constructed for each one to determine what overall bead types created the cluster (Fig. 13).

Bead Analysis

Double-Link Method

Again the Double-Link method was used but this time to group bead types. Exactly the same procedure was used as for the burials. This time a higher cluster coefficient of 71.2 was calculated, indicating the impossibility of neatly seriating the bead types. The types fell into fairly obvious clusters just as the burials did. In Table 12 the bead types composing each cluster are listed. Any bead type not listed either had very low coefficients or did not fit neatly into one of the clusters. What these clusters mean culturally will not be pursued to any great extent. This study will test, though, how each of the main groupings of bead types as suggested by the Double-Link method and the typology provided by Sprague, changed with time. The groups tested will be the #9 seed beads, the #6 seed beads, the #5 pony beads, the faceted beads, and the wound beads.

The procedure adopted to test how these bead groupings changed with time was the simple chi-square. In order to accomplish this, all the dated burials were listed with their prominent bead types. The time period was divided into burials following 1881 and those before 1878. For each bead grouping, the frequency of the bead types present for the period following 1881 was counted, then counted for the period before 1878. Table 13 gives the frequency of bead types for each grouping and each time period. The number of burials in each time period is also needed. They are twelve for the period following 1881 and forty-six for the period before 1878.

Table 13

The Frequency of Bead Types Present

For Each Bead Grouping and Each Time Period

	Seed #9	Seed #6	Pony #5	Wound	Faceted
Following 1881	70(40.7)	8(14.5)	4(8.4)	7(5.6)	9(14.5)
Before 1878	127(156.3)	62(55.5)	36(31.6)	20(21.4)	61(55.5)

* Figures indicate expected frequencies for use in chi-square analysis.

Each bead grouping was tested for change with time singly. The example for the #9 seed bead grouping follows:

$$\chi^2 = \sum \frac{(O-E)^2}{E} = \frac{(O_+ - E_+)^2}{E_+} + \frac{(O_- - E_-)^2}{E_-}$$

$E_+ =$ expected frequency of bead types present following 1881

$E_+ = A_{\#9}\frac{n_+}{n}$, $n_+ =$ number of dated burials following 1881 = 12

$n =$ total number of dated burials = 58

$A_{\#9} =$ total frequency of #9 seed bead types present for all dated burials = 197

$E_- =$ expected frequency of bead types present before 1878

$E_- = A_{\#9}\frac{n_-}{n}$; $n_- =$ number of dated burials before 1878 = 46

$$E_+ = 197\,\frac{12}{58} = 40.7\ ,\quad E_- = 197\,\frac{46}{58} = 156.3$$

$$\chi^2 = \frac{(70-40.7)^2}{40.7} + \frac{(127-156.3)^2}{156.3} = 20.94$$

$df =$ degrees of freedom = 1

From the chi-square distribution table in McNemar (1962: 428-9), this chi-square value at one degree of freedom has a probability of happening purely by chance less than once in one-thousand occurrences. This strongly indicates the #9 seed bead did, indeed, change usage from the period before 1878 to the period following 1881. From Table 15 it was obvious that the #9 seed bead was used more in the later period by the individuals connected with the dated burials. Table 14 gives the probabilities that the other beads changed in usage from before 1878 to the period following 1881.

Table 14

The Probability for Various Bead Groupings

That the Difference They Showed With Time Was Due To Chance

	#9 Seed	#6 Seed	#5 Pony	Wound	Faceted
Probability	0.001	0.10	0.10	0.44	0.20

It might be added parenthetically that for a gambler the probabilities that #6 seed, #5 pony, and faceted beads changed with time are good, but to the statistician they are entirely unacceptable. Only the #9 seed beads could be accepted as changing frequency with time. The original table from which the figures for the chi-square were drawn is listed in the appendix (Table 14).

The results of the chi-square analysis will be discussed more fully in Chapter V.

Program Seriate

As with burials, the purpose of running the Program Seriate on the bead types was for a more refined analysis of a few select types. The more abundant types were desired. In order to present a fairly balanced picture of necklace type beads and garment beads, fourteen pony, wound, and faceted bead types were chosen according to those which were found in the most burials. Sixteen seed bead types were chosen on similar grounds. Thirty bead types, then, were analyzed. The bead types listed by number are found in Table 16.

Table 16

Bead Types Used in Program Seriate by Number

2	22	64	86	114
4	24	70	89	120
5	29	71	96	129
6	32	75	107	131
18	47	76	110	134
21	60	82	113	137

Again the ordered matrix which accompanies the seriated elements was requested and is found in the appendix (Table 17). Ten orderings were requested as was done with the burials. The Ordering Coefficient H, and the Matrix Coefficient C for each ordering, are recorded in Table 18.

Table 18

A List Giving Coefficient H and Coefficient C

For Each Ordering

Ordering	Coefficient H	Coefficient C
1	0.34269×10^{7}	1.08965
2	0.33956×10^{7}	1.07969
3	0.34269×10^{7}	1.08965
4	0.34269×10^{7}	1.08965
5	0.34269×10^{7}	1.08965
6	0.33956×10^{7}	1.07969
7	0.34269×10^{7}	1.08965
8	0.33956×10^{7}	1.07969
9	0.34269×10^{7}	1.08965
10	0.34269×10^{7}	1.08965
Data Matrix	-0.20530×10^{6}	-0.652794×10^{-1}

A histogram was constructed which presented the frequency distribution of the coefficients in order to discover any natural breaks (Fig. 14). The natural break for the lower coefficient values was chosen at 161-180 and the higher at 241-260.

Once the breaks were determined, the values on the ordered similarity matrix for bead types were hatched for values above 161 and cross-hatched for values above 241.

Weighted Pair-Group Method

The same computer program used for the weighted pair-group method in clustering burials was used for clustering bead types. The program was used without the 0.03 criterion.

The thirty bead types previously seriated by the Program Seriate were clustered by the WPGM. A list of them is furnished in Table 16.

The results of the WGPM are found in Fig. 14.

As a brief preliminary summary, Chapter V has discussed difficulties inherent in the basic data and connections between analytical data. The difficulties, briefly, involved native individuality, brief period of burial ground use, and the limitation of the study to beads as a characterization of the burial. The connections studied noted the associations between the Double-Link method and the following: the results of the Weighted Pair-Group method, wealth as determined by bead content, age distinctions of adult and infant in particular, spatial location, and finally dated burials. What follows concerns the R-type analysis done on bead types.

Discussion of Bead Type Analysis

The discussion of the bead type analysis played a secondary part in this study. Subjects of discussion will cover: The clusters established by the Double-Link method as characterized by the burials that contain the beads, the relation of clusters to time, the inconclusive results of the seriation by the Program Seriate, and the added information useful to the R-technique ogives discussed previously under the burial analysis discussion in this chapter.

The biggest effort put forth in the bead analysis involved the clustering of bead types by means of the Double-Link method. Table 12 lists the types in their respective clusters. Cluster I contained primarily the more plentiful #9 seed beads; II contained the rarer #9 seed beads; III contained primarily round and round faceted beads of a #4 size; IV contained predominantly green and blue faceted beads of a few sizes; V appropriately contained chiefly the more plentiful #5 pony beads with a significant contribution from faceted beads; VI had a varied assortment of wound, faceted and #6 seed beads; and finally, VII represented the largest collection and contained a few of every size and kind of bead found in the burials not listed in any of the other clusters. Notably, cluster VII had the most complete assemblages of #8 and #7 seed beads. These results had an important impact on strengthening the bead typology that Sprague created. Notably #9 seed beads, #6 seed beads, and #5 pony beads fell into separate clusters in a distinct manner. The fact that #7 and #8 seed beads fell together in Cluster VII suggested #7 and #8 may not have been culturally separated. The fact that #5 pony beads and faceted beads showed association in Cluster VII might prove useful. The potentially useful information contained in these clusters awaits more expert inspection. Enough uniformity between typology and clustering appears to warrant some attention.

Chi-square analysis showed wound beads were least affected by time and #9 seed beads were most affected by time. The significance values of the chi-square analysis of each type chiefly were for interest. Very little could be concluded from the results.

Seriation by the Program Seriate demonstrated no obvious connections with time, wealth, or age and sex. Judging from the clustering as represented by various shadings, determined from the frequency distribution of similarity values, a degree of connection between the clusters and #9 seed beads, #6 seed beads, #5 pony beads, and faceted beads existed. The results may have some meaning in a seriate sense but none has been found so far. The clustering did, though, give further support to the bead typology (Fig. 12 and Table 17).

The greatest support for the predominant bead types came from the Weighted Pair-Group method. The bead types chosen came from the Program Seriate and represented the most plentiful seed beads and the most plentiful pony, wound, and faceted beads. Note that by drawing a horizontal line at the 0.10 level that each size and type of bead seems to cluster into like groupings. In addition to further supporting typological distinctions, the WPGM results provided insight into a previous finding discussed under burial analysis in this chapter.

Investigation into what the first two clusters of #9 seed beads meant in relation to the results of the ogives drawn for the only cluster from the WPGM for burials as determined by the 0.28 line of similarity (Fig. 15). For the mentioned cluster of burials, the ogives showed no dramatic simultaneous rise in cumulative percentage for any specific type. When the #9 seed beads from the cluster mentioned at the beginning of this paragraph were combined, the contribution they made to the clustering of burials 69, 224, 26, 151, and 209 showed dramatic significance. For the burials mentioned they contributed in the order the burials are listed as follows: 66.4%, 64.8%, 32.3%, 46.5%, and 12.3%. The average for all burials equaled a 44.4% contribution to the clustering. Further work of correlating the two WPGM results for beads and burials suggests a good future direction for this study. Trends up to this point have been rough to pin-point. The more refined results from the Program Seriate and WPGM would better focus on the dynamics of the burial site.

In concluding the discussion of bead analysis, the most outstanding feature involved the repeated consistency found between Sprague's established typology and the clusters from each method. Of measurable importance also, a connection developed between the burial clusters from the WPGM and the bead type clusters from the WPGM. This concludes the discussion of Chapter V.

Chapter V has examined the Double-Link method as an important possibility for arranging large numbers of attributes or entities, in both burial and bead analysis. Although connection between available control factors and the Double-Link method were not certain, the connections appeared striking enough to indicate the usefulness of the Double-Link method as a preliminary means of organizing entities and attributes, at least.

CHAPTER VI

CONCLUSION

Numerical classification has gained much sophistication in a wide range of fields since Harold Driver and Alfred L. Kroeber began using the methods in the early 1930's. Many fields have borrowed from and added to numerical classification fusing it into a powerful interdisciplinary method. Some of these fields are biology, psychology, and anthropology. In 1963 a standardized procedure became available as the result of Robert R. Sokal and Peter H. A. Sneath in their book Principles of Numerical Taxonomy. The book raised a great deal of controversy but the major part of it remains intact as still acceptable. As Sokal and Sneath pointed out, the advent of the computer made classification by numerical means a possibility in many cases which before were impossible. Generally the results from these computer methods and numerical classification in general display a great deal of uniformity, not to mention often a surprising accuracy judging from the time required to establish a complex classification. Numerical classification now has a legacy of experimental successes to support it.

Numerical classification in archaeology remained a curiosity until 1951 when W. S. Robinson in collaboration with George W. Brainerd developed a manual seriation program that worked. Brainerd suggested a matrix contouring method that formed a precursor to the clusters later recognizable in seriated matrices. Twelve years later Marcia and Robert Ascher presented the first computerized seriation method which proved successful. Further refinements to the Aschers' program came first through the efforts of Kuzara, Mead, and Dixon (1966) and later still further refinement came as the

Craytor and Johnson's Program Seriate (1968). A final boost to archaeological numerical classification came through the ingenious paper by Colin Renfrew and Gene Sterud in 1969 which outlined two methods for seriating that required no computer and could be accomplished in a reasonable time period given a small enough matrix. All these innovations have made numerical classification a certain tool to be added to the archaeologist's methods.

Use of three methods on Palus burials and the beads found within the burials became the main interest for this thesis. One, the Weighted Pair-Group method, comes from biology and directly from Principles of Numerical Taxonomy. The other two are seriation methods from archaeology, the Program Seriate of Craytor and Johnson, and the Double-Link method by Renfrew and Sterud, with total emphasis resting on the latter. The large number of bead types and burials made these methods attractive since similarity matrices normally work best with a large number of attributes for Q-matrix analysis and entities for R-matrix analysis.

Using the analytical results from the three methods for both burials and beads a few conclusions about Palus cultural practices appeared noticeable. The low association between burials as a result of bead assemblages, the wide variability in number of beads per burial, and the low association between burials pointed to individuality in the use of beads, perhaps even individuality within the society. Also, the unequal distribution of beads may have meant an unequal distribution of wealth. Besides the individual nature of the burials, they seemed to demonstrate a pattern of burial placement with time. The pattern involved placing the burials in a progressively more easterly direction as they became more recent. Three results support this conclusion: (1) Clusters other than the largest and transitional tended to be earlier and located in the west end of the burial ground as decided by dates associated with the smaller clusters and by plotting the location of the clusters; (2) #6 seed beads found primarily in Cluster A demonstrated by chi-square a weak tendency toward an early origin and diminishing popularity with time; (3) Seriation by the Program Seriate which has a rough connection with dated burials indicated an easterly interment pattern with time. Finally, in connection with the bead analysis, clustering from every one of the three methods displayed a remarkable consistency with the typology established by Sprague. With more knowledge of the Palus culture, better assessments of the numerical methods can be made.

Time, wealth, location, and age all related to the burial clusters established by the Double-Link method. The many aspects relating to the burial clusters gave substantial evidence to support the conclusion that the clusters, indeed, reflected a general cultural factor. Since both the Program Seriate and Weighted Pair-Group method both used the same basic data matrix, they also reflected the same general cultural factor. If any conclusion must develop from any study of this nature, it should first involve whether a classification reflects a general cultural factor or not.

Numerical analysis has made large strides since the time of Boas at the turn of the century. A great deal of useful information has appeared under the aegis of numerical analysis. In this age of computation it is not the methods that prove faulty, just the people that use them.

TABLE 12

A Listing of the Bead Types that Formed Each Cluster

by the Double-Link Method

Cluster I
- #9 Seed Beads
  - Cornaline d'Aleppo
  - Red translucent
  - Light green opaque
  - Dark green translucent
  - Light blue opaque
  - Dark blue opaque
  - Pink opaque
  - Pink translucent
  - Yellow opaque
  - Tan opaque
  - Black
  - Robin's egg blue
  - Deep robin's egg blue
  - Pea green opaque
  - Brown translucent
- #2½ Wound
  - Robin's egg blue

Cluster II
- #9 Seed Beads
  - Light green translucent
  - Light blue translucent
  - Faint blue
  - Yellow translucent
  - Tan translucent
  - Pea green opaque
- #3 Pony Beads
  - Robin's egg blue
- 9mm Biconical
  - Robin's egg blue

Cluster III
- #8 Seed Beads
  - Black
- #7 Seed Beads
  - Green Core Cornaline d'Aleppo
- #6 Seed Beads
  - White

Cluster III (cont.)
  - Cornaline d'Aleppo
  - Red translucent
  - Dark green translucent
  - Dark blue translucent
  - Pink opaque
  - Tan opaque
  - Purple
  - Black
  - Deep robin's egg blue
- #4 Round Faceted Beads
  - Yellow translucent
  - Pink translucent
- #4 Round Beads
  - Dark blue opaque
  - Opal
  - Pearl
  - Light blue opaque
- #3 Wound Beads
  - Robin's egg blue

Cluster IV
- #10 Seed Beads
  - White
- #8 Seed Beads
  - Dark green translucent
  - Dark blue opaque
- #3½ Faceted Beads
  - Dark green translucent
  - Dark blue translucent
  - Blue/white
  - Faint blue
  - Purple
- #3 Faceted Beads
  - Dark blue translucent

Cluster IV(cont.)
Tan translucent
#2½ Faceted Beads
Dark blue translucent

Cluster V
#9 Seed Beads
Light green translucent
#8 Seed Beads
Milk white
#5 Pony Beads
White
Cornaline d'Aleppo
Dark green translucent
Pink opaque
Tan opaque
Black
Robin's egg blue
Milk white
#3 Pony Beads
White
Milk white
#3½ Faceted Beads
Light green translucent
Tan translucent
#3 Faceted Beads
Blue/white
Purple
#2½ Faceted Beads
Dark green translucent
Dark blue translucent
Blue/white

Cluster VI
#6 Seed Beads
Robin's egg blue
#2½ Wound Beads
Dark green opaque
Black
#3½ Wound Beads
Robin's egg blue
#3 Faceted Beads
Dark green translucent
Robin's egg blue
#4 Round Faceted Beads
Black
8mmX6mm Conical Faceted with Transverse Hole in Bore Beads

Cluster VI(cont.)
Black
#3 Fancy Beads
Round mold made, white with yellow glaze wearing off

Cluster VII
#9 Seed Beads
Light blue translucent
#8 Seed Beads
Red translucent
Light blue opaque
Dark blue translucent
Pink opaque
Pink translucent
Yellow opaque
Yellow translucent
#7 Seed Beads
Cornaline d'Aleppo
Dark green translucent
Pink opaque
Black
#6 Seed Beads
Dark blue opaque
Yellow opaque
#10 Seed Beads
Pink opaque
Black
#5 Pony Beads
Green core Cornaline d'Aleppo
Dark blue opaque
Yellow opaque
Tan opaque
#4 Pony Beads
White
Robin's egg blue
#3½ Pony Beads
White
Cornaline d'Aleppo
Black
#3 Pony Beads
Cornaline d'Aleppo

Cluster VII(cont.)

<u>#2½ Pony Beads</u>
Cornaline d'Aleppo
<u>#3 Wound Beads</u>
Light green opaque
Light green translucent
Dark blue translucent
Light blue opaque
#2½ Wound Beads
Cornaline d'Aleppo
Light green translucent
Dark green opaque
<u>#2½ Wound Beads</u>
Light blue opaque
Yellow core Cornaline d'Aleppo
Tan translucent
Robin's egg blue
<u>10mm Wound Beads</u>
White
Cornaline d'Aleppo
Dark blue translucent
Black
<u>#3½ Faceted Beads</u>
Milk white
Light blue translucent
Black
Clear
<u>#3 Faceted Beads</u>
Light blue opaque
<u>#2½ Faceted Beads</u>
Light blue opaque
Light blue translucent
Robin's egg blue
<u>9mm Faceted Beads</u>
Dark blue translucent
<u>10mm Faceted Beads</u>
Dark blue translucent
<u>#4 Round Faceted Beads</u>
Black
<u>#3½ Round Faceted Beads</u>
Black
<u>#3½ Round Faceted Beads</u>
Black
<u>#2½ Round Faceted Beads</u>
White
<u>#3 Mold Made Round Faceted Beads</u>
Black

Cluster VII(cont.)

<u>8mmX6mm Conical Faceted with Transverse Hole in Bore Beads</u>
Black
<u>7mmX8mm Biconical Faceted Beads</u>
Robin's egg blue
<u>8mmX10mm Biconical Faceted Beads</u>
Robin's egg blue
<u>10mm Biconical Faceted Beads</u>
Robin's egg blue
<u>#3 Round Beads</u>
Light blue
White
<u>#3 Round Paste Beads</u>
White
<u>6mmX6mm Round Oval Beads</u>
White
<u>10mmX5mm Oval</u>
White
<u>4mmX6mm Elliptical</u>
Yellow
<u>#3 Fused Wound Bead</u>
Robin's egg blue
<u>3mmX6mm Snail Bead</u>
White
<u>2mmX6mm Snail Beads</u>
White
Pink opaque
Light green
<u>#3½ Hexagonal Broken Cane Beads</u>
Dark blue translucent
<u>#4 Hexagonal Broken Cane Beads</u>
Tan
<u>#6 Hexagonal Broken Broken Cane Beads</u>
Black
<u>#5 Seed Beads, Blue and Pink on Grey Core</u>

Cluster VII (cont.)

<u>12mm Round Cornaline d'Aleppo Beads with white strip around middle</u>

<u>12mmX12mm Oval White Paste Beads with Blue and Red Stripes</u>

<u>6mmx6mm Oval White Beads with Pink Spiral</u>

<u>7mmX6mm Oval Milk White Beads with Pink and Blue on White Dots</u>

FIGURE 14

A Frequency Distribution of

Coefficient Values

For Bead Types