AN OSTEOMETRIC ANALYSIS OF THE ARCHAIC GRAY SITE POPULATION OF SOUTHERN SASKATCHEWAN

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"AN OSTEOMETRIC ANALYSIS OF THE ARCHAIC GRAY SITE POPULATION OF SOUTHERN SASKATCHEWAN"

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CHAPTER I

INTRODUCTION

Since its beginnings in 19th century Europe, osteometric analysis has changed emphasis from the description of individual measurements of bones (Hrdlicka, 1942), to the analysis of total morphological patterns. In recent years, these patterns have been assessed through multivariate statistics to discern inter- and intrapopulation variation (Chrichton, 1966), to determine population affinities (Howells, 1966) and to investigate human antiquity (McHenry and Corruccini, 1975). This study investigated the morphological variation within an archaeological sample of skeletons from the Gray Site, in southern Saskatchewan, Canada, through a series of multivariate analyses. From measurements of cranial and infracranial bones, an attempt was made to determine whether one or more morphologically distinct groups were represented.

Context and Problem

The Gray Site, believed to be representative of the Archaic Period, Oxbow Culture Tradition, is located in a farmer's field northwest of Swift Current, "in the rolling aeolian grassland of southwestern Saskatchewan" (So and Wade, 1975:1). Six different radiocarbon dates have been obtained, from six burial units distributed over the site. They are as follows (Millar et al., 1972:13):

Burial Unit	Sample Number	Date B.P.
30	S-706	3485± 195
59	S-693	3550± 295
65	S-707	3750± 180
42	S-646	3755± 100
23	S-619	4955± 165
26	S-647	5100± 390

The range of carbon dates is suggestive of the use of the burial ground for almost 2,000 years. If the dates are accurate, it might be expected that more than one biological population, in a temporal and/or spatial sense, buried their dead at the Gray Site. In their palaeodemographic analysis of the skeletal remains, So and Wade (1975:2-3) note the possibility that the six dated burial units may be separated by no more than 210 years:

> The dates from the Gray Site fall into two "clusters," with mean values at about 3600 and 5000 years B. P., respectively. However, if one adds two standard error units to the 3750 date and subtracts two units from the 5100 date, there remains a hiatus of only 210 years. Use of the site may have been less discontinuous than seems initially apparent on the basis of these relatively small number of dates.

Under the circumstances proposed by So and Wade then, it is conceivable that the Gray Site was used for a shorter period than the 2000 years suggested by the radiocarbon dates. In any event, it is not clear from the archaeological study of the site whether the burials can or cannot be separated into discrete population units. There were many more burial units than those dated, and they have not been correlated temporally or culturally. Hence, the objective of this thesis is to ascertain, through metric analysis, the presence of one or more populations, in the Gray Site skeletal remains.

CHAPTER II

METHODS AND MATERIALS

Sample

By 1975, after four separate excavations, 305 individual skeletons had been recovered from the Gray Site. Five different burial types were observed by Millar *et al.*, and the presence of at least two more variations has been suggested (Knudsen, 1975). The burial types excavated were: bundle, extended, mass, circular, and "t" type (Millar et al., 1972).

Of the 305 individuals, only 110 skeletons were suitable for this analysis. Individuals who were represented by only a few broken long bones were not included. Infants and most of the children were also excluded because of the fragmentary nature of their skeletons. Thus, the analysis presented in this paper is based on the measurements of 110 partial and fragmentary adult and subadult individuals.

Measurement and Technique

Where possible, 53 cranial and 63 infracranial measurements were taken on each skeleton (Charts 2:1 and 2:2). Descriptions of the measurements may be found in the University of Toronto IBM Codification Manual (1971), devised by F. Jerome Melbye. Those measurements, marked by an asterisk, are defined by Olivier in *Practical Anthropology*.

The measurements were taken in millimetres with sliding, spreading and coordinate calipers, osteometric board, goniometer and tape. The raw data was keypunched onto IBM computer cards and the Statistical Package for the Social Sciences (SPSS) and CLUSTAN programmes were used to perform the statistical analyses.

CRANIAL METRICS

1. Glabello-Occipital Length
2. Maximum Cranial Breadth
3. Basion-Bregma Height
4. Auricular Height
5. Basion-Prosthion Length
6. Basion-Nasion Length
7. Minimum Frontal Breadth
8. Nasion-Gnathion Height
9. Nasion-Prosthion Height
10. Bizygomatic Breadth
11. Orbital Height
12. Orbital Breadth
*13. Biorbital Diameter
14. Nasal Length
15. Nasal Breadth
16. Alveolar Length
17. Alveolar Breadth
18. Palatal Length
19. Palatal Breadth
20. Biasterionic Breadth
21. Bistephanic Breadth
22. Bijugal Breadth
23. Ectochonchion Breadth
24. Simotic Chord
25. Bifrontal Chord
26. Naso-Frontal Subtense
27. Bimaxillary Chord
28. Zygomaxillare Subtense
*29. Basion-Porion Height
30. Nasion-Bregma Chord
31. Nasion-Bregma Subtense
32. Nasion Subtense Fraction
33. Bregma-Lambda Chord
34. Bregma-Lambda Subtense
35. Bregma Subtense Fraction
36. Lambda-Opisthion Chord
37. Lambda-Opisthion Subtense
38. Lambda Subtense Fraction
39. Frontal Arc
40. Parietal Arc
41. Occipital Arc
*42. Foraminal Length
*43. Foraminal Breadth
*44. Biporial Arc
*45. Maximum Horizontal Perimeter

MANDIBLE

1. Bicondylar Breadth
2. Minimum Ramus Breadth
3. Bigonial Breadth
4. Symphyseal Height
5. Body Length
6. Ramus Height
7. Coronoid Height
8. Mandibular Angle

CHART 2:1

INFRACRANIAL METRICS

HUMERUS

1. Maximum Length
2. Physiological Length
3. Maximum Shaft Diameter
4. Minimum Shaft Diameter
5. Maximum Head Diameter
6. Minimum Head Diameter
7. Epicondylar Breadth
8. Inferior Articular Surface Breadth

*9. Mid-shaft Circumference

ULNA

1. Maximum Length
2. Physiological Length
3. Olecranon Height
4. Olecranon Breadth

*5. Mid-shaft Circumference

RADIUS

1. Maximum Length
2. Physiological Length
3. Head Diameter
4. Distal End Breadth

*5. Mid-shaft Diameter

*6. Mid-shaft Circumference

FEMUR

1. Maximum Length
2. Physiological Length

*3. Bicondylar Length

4. Maximum Head Diameter
5. Proximal Anterior-Posterior Shaft Diameter
6. Proximal Medial-Lateral Shaft Diameter
7. Mid-shaft Anterior-Posterior Diameter
8. Mid-shaft Medial-Lateral Diameter

*9. Mid-shaft Circumference

TIBIA

1. Maximum Length
2. Physiological Length

*3. Maximum Length Without Intercondyloid Eminence

4. Condylar Breadth
5. Sagittal Cnemic Diameter
6. Transverse Cnemic Diameter
7. Sagittal Shaft Diameter
8. Transverse Shaft Diameter

*9. Mid-shaft Circumference

FIBULA

1. Maximum Length

INFRACRANIAL METRICS (Cont'd.)

SCAPULA

1. Maximum Length
2. Maximum Breadth
3. Glenoid Fossa Length
4. Glenoid Fossa Breadth

*5. Spine Length

CLAVICLE

1. Maximum Length
2. Shaft Diameter

*3. Mid-shaft Circumference

*4. Lateral Breadth

CALCANEUS

1. Maximum Length
2. Maximum Breadth
3. Minimum Breadth
4. Maximum Height

PATELLA

1. Maximum Length
2. Maximum Breadth
3. Maximum Thickness

INNOMINATE

1. Height
2. Symphyseal Height
3. Symphyseal Breadth
4. Acetabulum-Pubis Length
5. Acetabulum-Ischium Length

*6. Maximum Breadth

*7. Maximum Ilio-Auricular Length

*8. Minimum Iliac Breadth

CHART 2:2

Limitations of the Data

The methodological problems that the analyst must deal with when doing such an analysis are numerous and often frustrating. First, the Gray Site interments were not limited to single graves (see previous subsection). When dealing with mass burials, bundle burials, etc., the problem of distinguishing individual skeletons from each other arises (see EcNx-1A-5). In the indistinguishable cases the bones were measured according to side rather than by age, sex and individual designation.

The second major obstacle was the necessity to limit the measurements to those bones that were without damage and/or deterioration. In several cases, suture obliteration prohibited measuring from certain designated cranial reference points, such as bregma and lambda. None of the measurements relying on these points could be taken; for example, bregma-lambda chord and nasion-bregma subtense. Other factors were warpage of the bones, from ground pressure, and post-recovery deterioration, such as crumbling of the long bone ephiphyses from the relative dryness of their storage area (Chart 2:3).

Problems were also apparent in the measurements, which were independent of the condition of the osteological material. Four measurements relied on arbitrary landmarks and the accuracy of these results may be questioned (Chart 2:4). Bistephanic breadth was taken in only two cases because temporal lines were almost always absent.

Methods

Of the measured individuals, 50 near complete adult and subadult crania were suitable for multivariate analysis (Table 2:1). The cranial variables were reduced to the 28 most attainable measurements (Chart 2:5) which excluded any of the measurements that relied on ambiguous landmarks. Missing values were then generated to complete the data set for the cluster and discriminant analyses.

Predicting Values

To predict the missing values multiple regressions were calculated for each variable.

MEASUREMENTS OF DIFFICULTY DUE TO LACK OF PRESERVATION

Byzygomatic Breadth

Nasal Length

Zygomaxillare Subtense

Scapula: Maximum Length
Maximum Breadth
Spine Length

Clavicle: Maximum Length
Lateral Breadth

Femur: Bicondylar Breadth

Tibia: Condylar Breadth

Innominate: Pubic Symphysis Height
Pubic Symphysis Breadth

CHART 2:3

MEASUREMENTS OF DIFFICULTY DUE TO AMBIGUITY OF LANDMARKS

Alveolar Length

Alveolar Breadth

Palatal Length

Palatal Breadth

Bistephanic Breadth

CHART 2:4

TABLE 2:1

CRANIA USED IN THE CLUSTER ANALYSIS

Cluster #	Vyvyan #	Burial #	Age	Sex	Cluster Group
1	6	G3B3 II	13-17	F	1
28	67	61	13-17	F	1
38	83	71	Adult	F	1
18	48	59	18-20	M	1
27	64	50	Adult	M	1
19	50	59	Adult	M	1
24	61	59	Adult	M	1
49	105	105	Adult	M	1
13	38	32	Adult	F	1
26	63	48	13-17	F	1
35	80	41	Adult	F	1
40	87	39	13-17	F	1
41	89	37	13-17	F	1
50	111	EcNx-^{1}/19	Adult	F	1
2	7	G3B4 III	Adult	F	2
7	20	33	18-20	F	2
14	40	34	Adult	M	2
47	103	91	18-20	F	2
15	41	34	Adult	M	2
23	60	54	Adult	M	2
3	8	G3B6	Adult	M	2
16	45	59	Adult	M	2
21	55	35	Adult	M	2
4	11	G8B3	Adult	F	2
32	75	66	Adult	F	2
5	13	G13B5	Adult	M	2
45	101	36	Adult	M	2
9	22	33	Adult	M	2
12	33	23	18-20	F	2

TABLE 2:1 (Cont'd.)

Cluster #	Vyvyan #	Burial #	Age	Sex	Cluster Group
6	1	33	13-17	M	3
46	102	36	Adult	F	3
36	81	73	Adult	F	3
25	62	56	Adult	M	3
29	68	61	Adult	M	3
39	84	71	13-17	M	3
42	91	37	Adult	M	3
10	23	27	Adult	M	3
17	47	59	18-20	M	3
33	76	65	Adult	M	3
30	70	46	Adult	M	3
34	77	44	18-20	M	3
37	82	70	Adult	F	3
44	98	76	Adult	M	3
8	21	33	Adult	F	3
22	56	35	Adult	F	3
48	104	88	Adult	F	3
11	32	23	18-20	F	3
20	52	35	Adult	M	3
31	73	68	Adult	F	3
43	92	83	Adult	M	3

CRANIAL VARIABLES USED IN THE CLUSTER ANALYSIS

1. Glabello-Occipital Length
2. Maximum Cranial Breadth
3. Auricular Height
4. Basion-Prosthion Length
5. Basion-Nasion Length
6. Minimum Frontal Breadth
7. Nasion-Prosthion Height
8. Orbital Height
9. Orbital Breadth
10. Biorbital Diameter
11. Nasal Breadth
12. Biasterionic Breadth
13. Naso-Frontal Subtense
14. Ectochonchion Breadth
15. Simotic Chord
16. Bifrontal Chord
17. Bimaxillary Chord
18. Nasion-Bregma Chord
19. Bregma-Subtense Fraction
20. Nasion-Subtense Fraction
21. Bregma-Lambda Chord
22. Bregma-Lambda Subtense
23. Bregma-Subtense Fraction
24. Frontal Arc
25. Parietal Arc
26. Occipital Arc
27. Biporial Arc
28. Maximum Horizontal Perimeter

CHART 2:5

> Multiple regression is a general statistical technique through which one can analyse the relationship between a dependent or criterion variable and a set of independent or predictor variables. Multiple regression may be viewed as a descriptive tool by which the linear dependence of one variable on others is summarized and decomposed, or as an inferential tool by which the relationships in the population are evaluated from the examination of sample data (Kim and Kohout, 1975:321).

Multiple regression summarized the relationship between each cranial measurement and a predicted set of other cranial measurements. In doing so, correlation coefficients and constants for each variable were calculated and these were subsequently used in the formula to predict missing values. The formula used was:

$$Y = XB + C$$

where Y = the predicted value of the dependent variable
X = the value of the independent variable
B = Beta, the standardized regression coefficient
C = the constant

or

Glabello-Occipital Length = Maximum Cranial Breadth x .80 + 73.2

X, B and C were all calculated in the multiple regression results. Multiple regressions for all of the variables were done twice, once for females and once for males. The appropriate figures were then entered into the equation to predict the missing values for each sex.

<u>The Cluster Analysis</u>

The cluster analysis was performed by the 1975 version of the Clustan 1C programme. CLUSTAN, written in the Fortran IV language, is a single programme containing a set of optional statistical procedures. The different procedures are sub-routines whose selection is specified by the CLUSTAN driver. To perform the cluster analysis the following multivariate statistics were computed for the 50 Gray Site crania:

1. Similarity Matrix
2. Nearest Neighbours or single K linkage
3. Ward's Method
4. A relocating procedure
5. Dendrogram plot of squared Eucledian Distances

The triangular array of similarity coefficients measured the similarity between the individuals in the sample. The similarity matrix arranged the crania so that the similar cases were placed close together and the dissimilar cases were placed far apart. The similarity coefficients were grouped into evenly spaced classes in order of importance. For example:

2	2		
3	4	4	
4	2	3	3
	1	2	3

Where cases 1 and 4 merge into a single cluster at a criterion value of 2. Cases 2 and 3 merge at a criterion value of 4 and so on.

Nearest Neighbour analysis was then computed to measure the distance between each point and all of the other points in a multidimensional space. The distance between any two groups is the measured distance between their closest two members. Both of these procedures were required to order the Ward's hierarchical analysis.

Ward's Method - Ward's method was implemented to form hierarchical groups of subsets, each of which contained individual members who were maximally similar to each other with respect to the specified cranial variables. Ward's method used a series of hierarchical steps to reduce the 50 possible groups to one group. The procedure uses an objective function termed the error sum of squares (ESS = the sum of the squared deviations about the group mean). The ESS reflects a loss of information resulting from treating many scores, in this case 50, with one mean rather than with 50 individual scores. The formula is:

$$ESS = \sum_{i=1}^{N} x^2 i - \frac{1}{N} (\sum_{i=1}^{N} xi)^2$$

where xi is the score for the ith individual (Ward, 1963:237). Subsets are produced by hierarchical steps which minimize the ESS, optimally to 0.0, so the resultant groups have an ESS that is no greater than what it would be with every other combination of individuals.

In summary, the hierarchy procedure began with 50 clusters, each cluster consisting of one of 50 crania. In a series of fusion cycles the most similar clusters were grouped into single clusters until all had been fused into one terminal cluster.

As a check, the relocate procedure was implemented to test the stability of the clusters that were computed by Ward's method. In turn, each of the 50 cases was reconsidered and its similarity with each of the different clusters was computed.

> Suppose that the similarity between object X and its parent cluster P is S (P, X) and the similarity between X and any other cluster Q, is S (Q, X), then if S (Q, X) exceeds S (P, X) then the method moves X from cluster P to cluster Q (Wishart, 1975:43).

When this change occurs the centroids of the clusters are recomputed to account for the change. The relocate procedure continues until no individuals are rearranged during one complete scan and the clusters are maximally stable.

The Discriminant Analysis

The 50 crania were subjected to a discriminant analysis for two reasons: to check the distinctiveness of any groups proposed by the cluster analysis, and to classify the cases that were not entered into the cluster analysis, because of missing values, into one of the three groups proposed by the cluster analysis.

Discriminant functions were computed to determine the distinctiveness of the groups.

> The functions themselves each consist of a series of coefficients or weights, by which the measurement scores of an individual are multiplied and summed to give him a single score on that function.

> It is the centroids of these scores (i.e., the means of all individual scores) which locate the several groups with respect to one another (Crichton, 1966:55).

Discriminant analysis attempts to distinguish between different groups by forming linear combinations of discriminating variables. The formula is:

$$D_i = d_{i1} Z_1 + d_{i2} + \dots + d_{ip} Z_p$$

"where D_i is the score on the discriminant function i, the d's are weighting coefficients, and the Z's are the standardized values of the p discriminating variables used in the analysis" (Klecka, 1975:434).

Often, in some data lists, there are too many variables to compute a satisfactory discrimination. When this problem arises a stepwise procedure can be implemented which reads through all of the variables and selects the single best discriminator. The variables are reread and a second discriminator, one which improves the discriminating ability in combination with the first variable, is selected. At each step a variable may be removed from the discriminating list if its discriminating power decreases with the addition of other variables. The process stops when the remaining variables no longer contribute to the discriminating power of the variable list.

The SPSS version of discriminant function analysis was used to check and classify the Gray Site crania. The discriminant scores were computed by multiplying each discriminant variable by its corresponding d_i value (see previous formula) and adding these products together. Standard discriminant function coefficients were used so the score from each function had a mean of zero and a standard deviation of one.

> Unstandardized coefficients do not report the relative importance of the variables since they have not been adjusted for the measurement scales and variability in the original values (Klecka, 1975:444).

By averaging the scores for the cases the group mean (or centroid - the most probable location of a case from a specific group in the discriminant function space) was computed.

Eigenvalues and their associated canonical correlations were computed to determine the relative ability of each function to separate the groups in question. An eigenvalue is a measure of the relative importance of a function. "The sum of the eigenvalue is a measure of the total variance existing in the discriminating variables" (Klecka, 1970:442). Thus, the higher the eigenvalue and canonical correlation the higher the discriminating ability of the function. When a single eigenvalue is expressed as a percentage of the total sum of eigenvalues the relative importance of the associated function can be seen.

The next procedure computed Wilks' lambda and the associated chi-square values for the two functions. Wilks' lambda used F ratios to test the distinctiveness of the group centroids. Group discrimination is measured by those variables which maximize the F ratio and minimize Wilks' lambda. The F ratio tests, "the statistical significance of the amount of centroid separation added by this [a specific] variable above and beyond the separation produced by the previously entered variables" (Klecka, 1975:453). The larger Wilks' lambda is, the less discriminating power it possesses. The accompanying chi-square gives the statistical significance of the Wilks' lambda.

Once the analysis phase of the discriminant analysis was completed the programme used the selected variables and their discriminant functions to classify cases whose group association was unknown.

> Once a set of variables is found which provides satisfactory discrimination for cases with unknown group membership, a set of classification functions can be derived which will permit the classification of new cases with unknown memberships (Klecka, 1975:434).

On the basis of the groups of crania defined by the cluster analysis, the remaining crania that were not used in the cluster analysis were entered into the discriminant analysis for classification. The next step in the analysis selected, from the original group of 50 crania, the individuals with the most complete infracranial skeletons. To compute the discriminant functions for the infracranial material would provide a classification scheme for the infracranial skeletons whose group membership was unknown. Of the 50 crania only 21 had near complete infracranial skeletons. (The results of the infracranial classification are based on only 21 cases and may not represent the true results. The results must not be regarded as conclusive until another discriminant analysis is done with a larger infracranial sample. This will entail further excavation of the site.)

A total of 46 infracranial measurements (Chart 2:6) on 21 infracranial skeletons (Table 2:2) were used in the discriminant analysis. When values were missing they were predicted by the same methods used to predict cranial data. The group association or membership for each of the 21 cases was known. The analysis computed discriminant functions for the infracranial material and provided a classification scheme for the remaining infracranial bones whose group association was unknown. The group association for these remains was unknown because none of the individuals had near complete skulls. Thus, they were not entered into the cluster analysis.

INFRACRANIAL VARIABLES USED IN THE DISCRIMINANT ANALYSIS

Right Humerus:
- Maximum Length
- Physiological Length
- Maximum Shaft Diameter
- Minimum Shaft Diameter
- Minimum Head Diameter
- Maximum Head Diameter
- Epicondylar Breadth
- Inferior Articular Surface Breadth
- Mid Shaft Circumference

Right Ulna:
- Maximum Length
- Physiological Length
- Olecranon Height
- Olecranon Breadth
- Mid Shaft Circumference

Right Radius:
- Maximum Length
- Physiological Length
- Head Diameter
- Distal End Breadth
- Mid Shaft Diameter
- Mid Shaft Circumference

Right Scapula:
- Glenoid Fossa Length
- Glenoid Fossa Breadth

Left Clavicle:
- Shaft Diameter
- Mid Shaft Circumference

INFRACRANIAL VARIABLES USED IN
THE DISCRIMINANT ANALYSIS (Cont'd.)

Right Femur:
- Maximum Length
- Physiological Length
- Maximum Head Diameter
- Proximal Anterior-Posterior Shaft Diameter
- Proximal Medial-Lateral Shaft Diameter
- Mid Shaft Anterior-Posterior Diameter
- Mid Shaft Medial-Lateral Diameter
- Mid Shaft Circumference

Left Tibia:
- Maximum Length
- Physiological Length
- Maximum Length Minus Intercondyloid Eminence
- Sagittal Cnemic Diameter
- Transverse Cnemic Diameter
- Sagittal Shaft Diameter
- Transverse Shaft Diameter
- Mid Shaft Circumference

Innominate:
- Height
- Acetabulum-Pubis Length
- Acetabulum-Ischium Length
- Maximum Breadth
- Maximum Ilio-Auricular Breadth
- Minimum Iliac Breadth

CHART 2:6

TABLE 2:2

INFRACRANIAL SKELETONS USED
IN DISCRIMINANT ANALYSIS

Cluster #	Vyvyan #	Sex	Cluster Group
1	6	F	1
13	38	F	1
18	48	M	1
26	63	F	1
35	80	F	1
38	83	F	1
40	87	F	1
49	105	M	1
5	13	M	2
14	40	M	2
15	41	M	2
16	45	M	2
47	103	F	2
45	101	M	2
25	62	M	3
33	76	M	3
34	77	M	3
37	82	M	3
39	84	M	3
43	92	M	3
46	102	F	3

CHAPTER III

RESULTS

Cluster Analysis

The results of the hierarchical fusions are presented in a dendrogram (Figure 3:1). The individual crania were plotted on the X axis and the distance coefficients on the Y axis. At the Eucledian distance coefficient level 1, pairs of similar individuals were plotted. As the distance coefficients increased in number more cases were combined, into larger groups, as they approached a common similarity level. In the accompanying dendrogram, at the distance coefficient 15, there were three distinct groups of crania. Two of these groups "fused" at the distance coefficient 21, while the resultant two groups fused at the distance coefficient 43.

Interpretation of the dendrogram suggested the existence of three distinct groups being represented in the Gray Site remains. Groups two and three were distinct entities, yet they reached a level of similarity with each other at the distance coefficient 21. This relatively low distance measure may be indicative of two groups who were not completely different (biologically) from each other. The first group of individuals in the dendrogram was clearly unique and definitely unrelated to the latter two groups. This group did not begin to appear similar to groups two and three until they reached a distance coefficient of 43.

Within the first entity (the first 14 individuals in the dendrogram) the males and females have been fused according to sex, suggesting a sex distinction in cranial metrics. In group two (the next 15 individuals in the dendrogram) the partitions between male and female fusions were not so clear, the sexes being interspersed with each other (with the exception of five males) and often not clustering together at all. Within this group, the cranial metrics for males and females were not

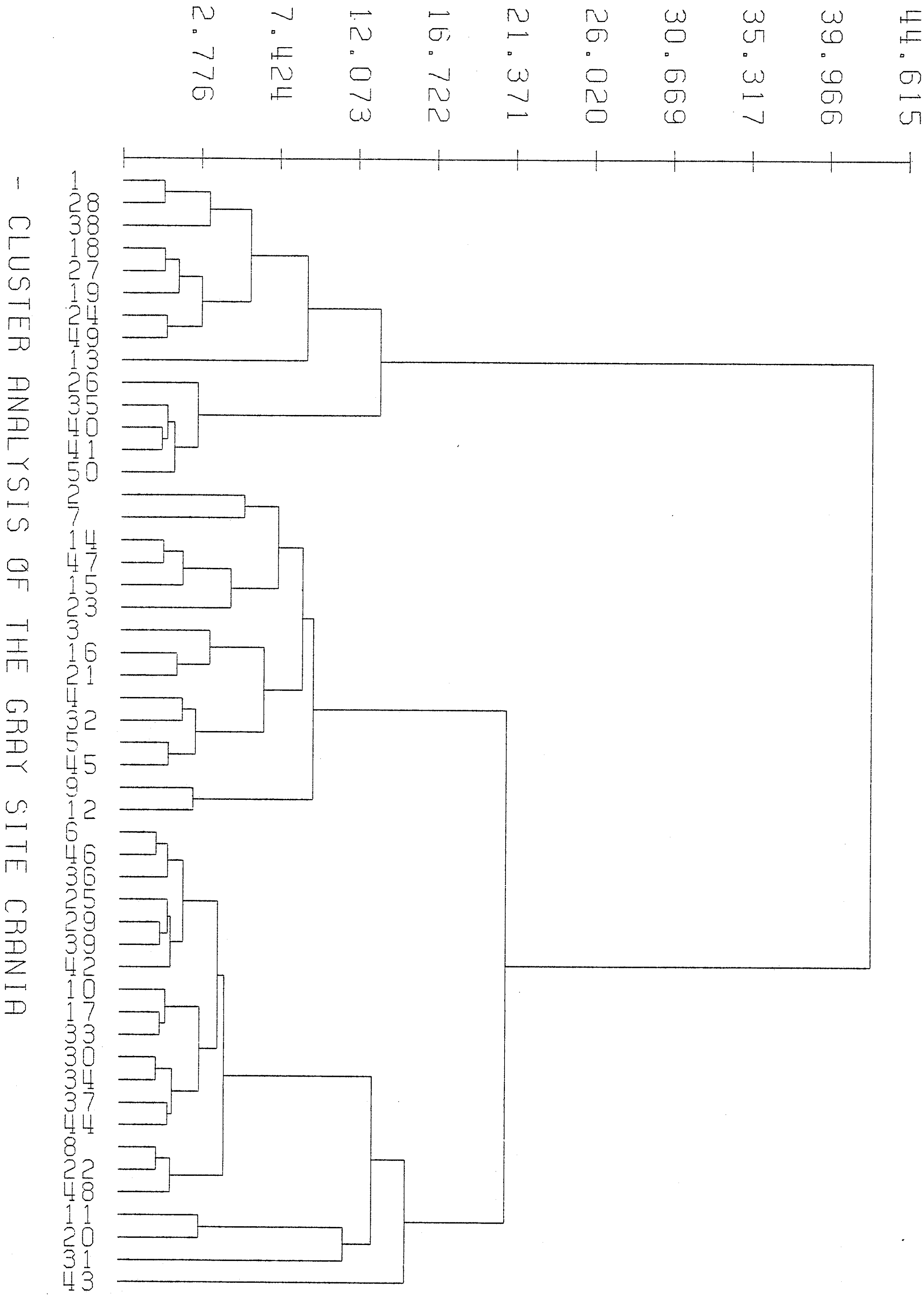

Figure 3:1--Dendrogram of the Gray Site Crania.

particularly distinct and a considerable amount of overlap was present. In the third entity (the remaining 21 individuals in the dendrogram) there was a fusion of 11 males and a fusion of four females. The remaining seven cases were interspersed with each other randomly, rather than according to sex. The pattern suggested a male and a female "type" with an overlap of variation existing in this group of individuals (Table 2:1).

Summary

The cluster analysis revealed a dendrogram delineating three distinct groups of crania, each group consisting of males and females. The uniqueness of group one was evident, while the uniqueness of group two to group three required further testing.

Discriminant Analyses

Discriminant Analysis One

Two discriminant functions were computed for 12 cranial variables selected by the stepwise procedure. The variables and their standardized discriminant function coefficients are presented in Table 3:1. Table 3:2 lists the centroids of each group and a territorial map plotting the centroids is shown in Figure 3:2.

The group centroids suggested the existence of three distinct groups. The eigenvalues and canonical correlations for the functions indicated that the first function was the better discriminator of the two (see Table 3:3). The relative percentage for the first function accounted for 71.62% of the observed variation in the crania. Although the second function was not as strong a discriminator as the first function, it did represent an important power. Of the expressed cranial variation, 28.38% was accounted for by the second function. These interpretations were supported by a lower value of Wilks' lambda, and a higher chi-square value for the first function (Table 3:4).

Using these computations, the discriminant analysis relocated any cases within the specified groups which had a higher statistical association with another of the defined groups. The results of this test are presented in Table 3:5.

TABLE 3:1

STANDARDIZED DISCRIMINANT FUNCTION SCORES
FOR DISCRIMINANT ANALYSIS ONE

	Function 1	Function 2
Basion Prosthion	0.129	-0.184
Basion Nasion	0.1016	0.184
Minimum Frontal	0.513	0.049
Nasion Prosthion	-0.283	0.205
Orbital Breadth	0.265	-0.496
Biasterionic Breadth	0.086	-0.247
Ectochonchion	0.362	-0.073
Simotic Chord	0.129	0.084
Bimaxillary Chord	-0.036	-0.231
Nasion Bregma Chord	-0.462	-0.618
Bregma Lambda Chord	-0.164	-0.188
Occipital Arc	0.130	-0.087

TABLE 3:2

CENTROIDS OF EACH GROUP FOR
DISCRIMINANT ANALYSIS ONE

	Function 1	Function 2
Group 1	-1.104	0.882
Group 2	1.273	0.523
Group 3	-0.182	-1.010

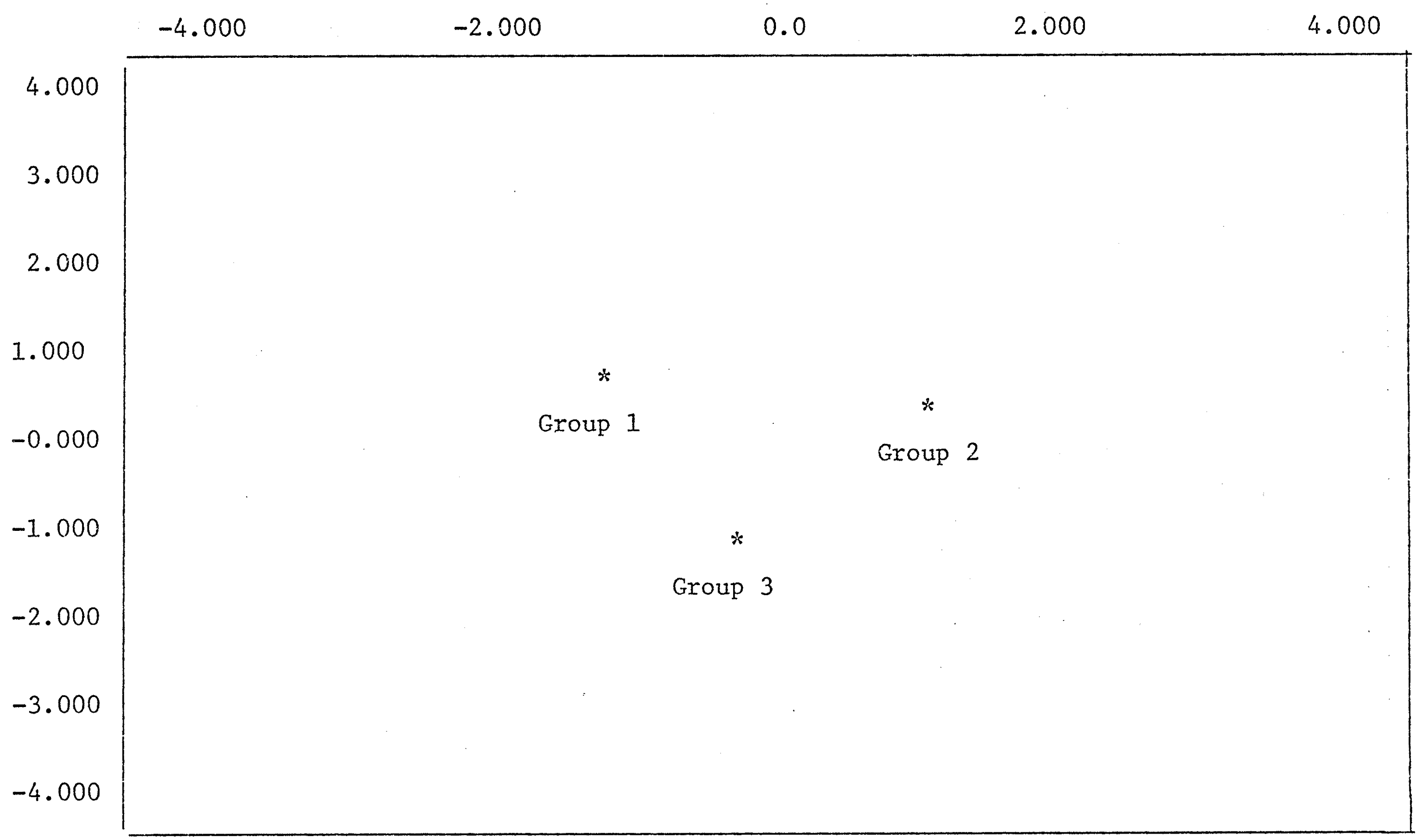

Figure 3:2--Territorial Map of Group Centroids for Discriminant Analysis One.
*Discriminant Score 1 is horizontal and Score 2 is vertical.

TABLE 3:3

COMPUTATIONS OF DISCRIMINANT ANALYSIS ONE

Function	Eigenvalue	Relative Percentage	Canonical Correlation
1	7.077	71.62	0.936
2	2.804	28.38	0.859

TABLE 3:4

COMPUTATIONS OF DISCRIMINANT ANALYSIS ONE

Functions Derived	Wilks' Lambda	Chi-square
0	0.032	138.72
1	0.262	54.11

TABLE 3:5

DISCRIMINANT ANALYSIS ONE CLASSIFICATION
OF THE THREE GROUPS BASED ON TWO
DISCRIMINANT FUNCTIONS

Actual Group	Number of Cases	Predicted Group Membership Group 1	Group 2	Group 3
1	14	14	0	0
2	15	0	15	0
3	21	0	0	21

Percent of grouped cases correctly classified: 100.00%

On the basis of the three defined groups of crania and their two discriminant functions, the remaining twenty crania that were not used in the cluster analysis were entered into the discriminant analysis for classification. The results were:

TABLE 3:6

PREDICTED CLASSIFICATIONS OF UNGROUPED CRANIA

		Predicted Membership		
Actual Group	No. of Cases	Group 1	Group 2	Group 3
Ungrouped cases	20	4	5	11

At this stage, the discriminant analysis had provided the results of two separate analyses: a) it computed the distinctiveness of each of the three proposed groups of crania; and b) it classified a sample of 20 crania into the groups to which they were the most similar.

Discriminant Analysis Two

Of the 50 original crania, 21 had near complete infracranial remains. Discriminant functions were computed for those infracranial bones whose group association was known (Table 3:7). This provided a scheme for classifying the infracranial bones whose group association was unknown. The group association for these individuals was unknown because they lacked skulls or near complete skulls. These were not entered into the cluster analysis.

The results of this analysis (Tables 3:8, 3:9, and 3:10) are somewhat different from the results of the crania analysis. The first function was weighted much heavier in this analysis. It accounted for 88.42% of the infracranial variation. This was reflected in the canonical correlation, Wilks' lambda and chi-square values. The second function was

TABLE 3:7

RESULTS OF DISCRIMINANT ANALYSIS TWO
STANDARDIZED DISCRIMINANT
FUNCTION COEFFICIENTS

	Function 1	Function 2
R. Hum. Physio. Len.	0.132	-0.353
R. Hum. Max. Sh. Dia.	0.795	0.059
R. Hum. Min. Sh. Dia.	-0.293	-0.707
R. Hum. Max. Head Dia.	0.580	-0.421
R. Hum. Inf. Art. Sur.	-0.481	1.587
R. Hum. Max. Sh. Cir.	-1.172	0.126
R. Ulna Max. Len.	-0.718	1.331
R. Ulna Phy. Len.	0.540	-1.714
R. Ulna Olec. Hgt.	0.236	0.394
R. Scap. Glen. Len.	-0.175	-0.560
L. Clav. Max. Sha. Cir.	0.087	-0.727
R. Fem. Max. Sh. Cir.	-0.244	0.376
R. Hip Acet-Ish.	-0.157	-0.771

TABLE 3:8

COMPUTATIONS OF INFRACRANIAL CASES
DISCRIMINANT ANALYSIS TWO

Discriminant Function	Eigenvalue	Relative %	Canonical Correlation
1	306.31104	88.42	0.998
2	40.10623	11.58	0.988

TABLE 3:9

COMPUTATIONS OF DISCRIMINANT ANALYSIS TWO

Functions Derived	Wilks' Lambda	Chi-square
0	0.0001	103.884
1	0.0243	40.878

TABLE 3:10

GROUP CENTROIDS FOR DISCRIMINANT ANALYSIS TWO

	Function 1	Function 2
Group 1	1.19051	0.05394
Group 2	-0.85107	1.20552
Group 3	-0.73637	-1.27750

TABLE 3:11

PREDICTION RESULTS OF DISCRIMINANT ANALYSIS TWO

		Predicted Group Membership		
	No. of Cases	Group 1	Group 2	Group 3
Group 1	8	8	0	0
Group 2	6	0	6	0
Group 3	7	1	0	6
Ungrouped Cases	18	9	3	6

Percent of grouped cases correctly classified: 95.24%

considerably less important, however, it did account for 11.58% of the variation and should not be excluded from the analysis. In the first function, the centroid for the first group was far removed from that of the second and third groups, however the centroids for the latter two groups were very close. In the second function the centroids for all three groups were very distinct and separate. The discriminant functions placed the 21 infracranial skeletons, with the exception of one, into their actual groups. The 18 remaining infracranial skeletons whose group membership was unknown were classified by the discriminant analysis. The results are listed in Table 3:11.

Discriminant Analysis Three

The third discriminant analysis used the 21 complete skeletons, whose group membership was known, to classify the fragmentary cranial and infracranial material in a combined analysis. This procedure was implemented to determine if the individuals with partial skeletons would be classified into the same groups as when separate cranial and infracranial discriminant functions were used (Table 3:12).

The distinctiveness of the three groups of individuals was similar to the results of the infracranial classification analysis. The first function indicated that group one was very different from groups two and three. However groups two and three were very close. Although the second function indicates that the three groups were all very distinct entities, it expressed only 14.48% of the variation, whereas the first, and heaviest, function accounted for 85.52% of the observed cranial and infracranial variation. The results of these functions are listed in Tables 3:13, 3:14, and 3:15.

The analysis placed each of the 21 cases whose membership was known into their defined group of association and placed each of the 30 unclassified cases into their group of highest probable membership (Table 3:16).

Discriminant Analysis Four

The last discriminant analysis was computed to recheck the stability of the three groups defined by the cluster analysis. Of the 50 crania used in the cluster analysis only 21 had near complete infracranial

TABLE 3:12

RESULTS OF DISCRIMINANT ANALYSIS THREE
STANDARDIZED DISCRIMINANT
FUNCTION COEFFICIENTS

	Function 1	Function 2
Max. Cranial Bdth.	-0.224	0.149
Min. Frontal	-0.601	-0.531
Orbital Hgt.	-0.181	0.427
Orbital Bdth.	-0.338	0.235
Simotic Chord	0.105	-0.358
Nasion Bregma Chord	0.105	0.631
R. Scap. Glen. Len.	-0.456	0.099
L. Clav. Max. Shaft Cir.	0.178	0.093
L. Tibia Sagittal Dia.	-0.188	-0.239
R. Hip Max. Breadth	0.187	-0.171

TABLE 3:13

COMPUTATIONS OF DISCRIMINANT ANALYSIS THREE

Discriminant Function	Eigenvalue	Relative %	Canonical Correlation
1	70.30103	85.52	0.993
2	11.90578	14.48	0.960

TABLE 3:14

COMPUTATIONS OF DISCRIMINANT ANALYSIS THREE

Functions Derived	Wilks' Lambda	Chi-square
0	0.0011	85.307
1	0.0775	31.971

TABLE 3:15

CENTROIDS OF EACH GROUP FOR DISCRIMINANT ANALYSIS THREE

	Function 1	Function 2
Group 1	1.18137	0.09187
Group 2	-0.68769	-1.26597
Group 3	-0.88780	1.14350

TABLE 3:16

PREDICTION RESULTS OF DISCRIMINANT ANALYSIS THREE

		Predicted Group Membership		
Actual Group	No. of Cases	Group 1	Group 2	Group 3
1	8	8	0	0
2	6	0	6	0
3	7	0	0	7
Ungrouped	30	18	9	3

Percent of defined group cases correctly classified: 100%

skeletons. This analysis computed functions that would reclassify the remaining 29 crania of the original 50 and their incomplete infracranial skeletons. The group membership given by the cluster analysis and the group membership given by the discriminant analysis, for each case, were compared.

The results of the analysis were identical to the previous analysis, which classified cases whose group membership was unknown using cranial and infracranial measurements. The first function was weighted heavier and accounted for 85.52% of the expressed variation, and the second function accounted for 14.48% of the variation. In the first function, group one is very distinct and groups two and three are similar. The second function, however, indicated that all three groups were distinct from each other. The discriminating variables and computations are in Chart 3:1 and Tables 3:17, 3:18, 3:19, 3:20, and 3:21. Note that the discriminating variables in this analysis and the other combined analysis are the same.

Summary

Four separate discriminant analyses were performed. These were:

1. Three defined groups of crania computing the distinctiveness of each group and classifying a fourth group of crania whose group membership was unknown.
2. Three defined groups of infracranial skeletons computing the distinctiveness of each group and classifying a fourth group of infracranial skeletons whose group membership was unknown.
3. Three defined groups of cranial and infracranial skeletons computing the distinctiveness of each group and classifying a fourth group of cranial and infracranial skeletons whose group membership was unknown.
4. Three defined groups of cranial and infracranial skeletons computing the distinctiveness of each group and classifying a group of cranial and infracranial skeletons whose group membership was known.

The results of the first analysis, based on 50 complete crania, indicate the presence of three very distinct groups at the Gray Site. The remaining analyses, based on 21 complete skeletons, also indicate

DISCRIMINATING VARIABLES USED IN
DISCRIMINANT ANALYSIS FOUR

Cranial (12)	Infracranial (12)
Basion Prosthion	R. Humerus Physio. Length
Basion Nasion	R. Humerus Max. Shaft Dia.
Min. Frontal	R. Humerus Min. Shaft Dia.
Nasion Prosthion	R. Humerus Inf. Art. Surf.
Orbital Breadth	R. Humerus Max. Shaft Circ.
Biasterionic Bdth.	R. Ulna Max Length
Ectochonchion Bdth.	R. Ulna Physio Length
Simotic Chord	R. Ulna Olecranon Hgt.
Bimaxillary Chord	R. Scap. Glenoid Len.
Nasion Bregma Chord	R. Clavicle Circum.
Bregma Lambda Chord	R. Femur Shaft Circ.
Occipital Arc	R. Hip Actet-Ishium

Both 6 and 4 (10)

Max. Cranium
Min. Frontal
Orbital Hgt.
Orbital Bdth.
Simotic Chord
Nasion Bregma Chord
R. Scap. Glenoid Len.
L. Clav. Circum.
L. Tib. Sag. Shaft
R. Hip Max. Bdth.

CHART 3:1

TABLE 3:17

STANDARDIZED DISCRIMINANT FUNCTION SCORES
OF DISCRIMINANT ANALYSIS FOUR

	Function 1	Function 2
Max. Cranium	-0.023	0.014
Min. Frontal	-0.157	-0.139
Orbital Hgt.	-0.066	0.155
Orbital Bdth.	-0.191	0.133
Simotic Chord	0.049	-0.167
Nasion Bregma Chord	0.022	0.133
R. Scap. Glen. Len.	-0.122	0.026
L. Clav. Max. Cir.	0.028	0.015
L. Tibia Sagittal Dia.	-0.050	-0.063
R. Hip Max. Bdth.	0.018	-0.016

TABLE 3:18

COMPUTATIONS OF DISCRIMINANT ANALYSIS FOUR

Discriminant Function	Eigenvalue	Relative %	Canonical Correlation
1	70.30103	82.52	0.993
2	11.90578	14.48	0.960

TABLE 3:19

COMPUTATIONS OF DISCRIMINANT ANALYSIS FOUR

Functions Derived	Wilks' Lambda	Chi-square
0	0.0011	83.307
1	0.0775	31.971

TABLE 3:20

GROUP CENTROIDS FOR DISCRIMINANT ANALYSIS FOUR

	Function 1	Function 2
Group 1	1.18137	0.09187
Group 2	-0.68769	-1.26597
Group 3	-0.88780	1.14350

TABLE 3:21

PREDICTION RESULTS OF DISCRIMINANT ANALYSIS FOUR

		Predicted Group Membership		
Actual Group	No. of Cases	Group 1	Group 2	Group 3
1	8	8	0	0
2	6	0	6	0
3	7	0	0	7
Ungrouped	8	1	1	6

Percent of grouped cases correctly classified: 100%

the presence of three very distinct groups. In these latter three analyses the first discriminant functions showed that group one was very distinct from groups two and three and that groups two and three were indeed distinct entities but with centroids very close to each other. The similarity of groups two and three was observed in the dendrogram where they fused at the distance coefficient 21. The second discriminant function of the last three analyses showed the centroids for groups one, two and three to be well separated from each other and representative of three discrete entities.

The computations performed in the four analyses provided a scheme whereby the unclassified adult skeletons at the Gray Site could be assigned to one of the three groups. In some cases the predicted group membership of an individual based on cranial variables and then based on infracranial variables differed (Table 3:22). When this situation arose the individual was assigned to the predicted group in which he had the most discriminating variables (Table 3:23). For example, if a case was initially placed in group one on the basis of two discriminating cranial variables, and later placed in group three on the basis of ten infracranial variables, it was left in group three (Table 3:24). Ideally, another discriminant analysis would have been performed on the three groups after all of the unclassified cases were slotted. In doing so, the stability of each group would be rechecked and any mis-assigned cases would appear. Unfortunately, discriminant analyses will not accept any missing values into the defined groups which compute the functions.

TABLE 3:22

CLASSIFICATION OF UNGROUPED CASES
BY DISCRIMINANT ANALYSIS

Vyvyan #	Cranial Analysis	Infracranial Analysis	Both
2		1	1
4		1	1
8		1	
14	1		1
25		1	3
27	3		2
29		1	3
30	2		3
31	3		2
34	2		2
35	2		2
42	2		2
43	2	1	1
44	3	2	2
46		3	2
49		3	2
51	3		3
53	1		1
54	3		1
58	3	1	1
59	3	3	1
71		3	1
72	1	1	1
85	3	1	1
86		1	1
90	3	3	1
94	3		1
96		2	1
97	1	2	1
106		3	1
112		1	1

TABLE 3:23

DISCRIMINATING VARIABLES PRESENT
IN UNCLASSIFIED CASES

Vyvyan #	Cranial (12)	Infracranial (12)	Both (6 and 4)
2	0	11	3
4	0	10	3
8	11	4	6
14	7	0	4
25	0	5	2
27	4	0	1
29	3	0	1
30	7	0	5
31	2	0	1
34	2	0	1
35	5	0	3
42	5	0	4
43	3	6	6
44	0	6	1
46	0	0	1
49	0	6	0
51	8	0	5
53	8	0	3
54	4	0	4
58	1	7	3
59	5	8	6
71	0	6	2
72	2	8	5
85	4	5	4
86	0	6	2
90	3	1	2
94	3	0	3
96	0	1	0
97	3	1	1
106	0	7	2
112	0	3	0

TABLE 3:24

FURTHER PREDICTION OF UNGROUPED CASES
INTO ONE GROUP

Vyvyan #	Predicted Group
2	1
4	1
8	1
14	1
25	1
27	3
29	3
30	2
31	3
34	2
35	2
42	2
43	1
44	2
46	2
49	3
51	3
53	1
54	3
58	1
59	3
71	3
72	1
85	1
86	1
90	3
94	3 or 1
96	2
97	1
106	2
112	1

CHAPTER IV

CONCLUSIONS

Discussion

This analysis has confirmed the presence of three discrete skeletal populations at the Gray Site. Whether the groups exhibit synchronic or diachronic relationships with one another will only be determined through interpretation of the archaeological material of the site, and more secure dating of several individuals from each of the three proposed groups. Interpretation of the radiocarbon dates will then help in discerning the temporal dimensions of the group.

If additional radiocarbon dates cluster at one time period, this will indicate three contemporaneous and morphologically distinct groups of people, at the site. If the dates overlap, this will indicate use of the site through time by more than one distinct or unrelated group. If the dates cluster into two or three distinct time periods, this will suggest interrupted use of the site by either: 1) a single population that changed through time; or 2) by two or three different morphological groups.

The possible explanations for the occurrence of more than one population of people are numerous and far exceed the scope of this thesis. In consideration of additional radiocarbon dates a few possible explanations will be presented. Should additional radiocarbon dates support the first statement - the presence of three contemporary and distinct groups - then the genetic integrity of the groups could be explained by the effects of band social structure on the genetic composition of the populations. For example, Williams (1974:115), has suggested that hunting societies often used an exchange-of-wives system as a mechanism to enhance band alliances and inter-band social cohesion. The social strategy of these exchanges had genetic implications for the bands. "The females of these bands, that is, half of the reproductive population, transfers between these bands every generation." Thus, gene flow results from new genetic material being introduced into each generation, thereby maintaining the genetic distinctiveness of each group.

If the second premise - the presence of distinct populations overlapped in time - is supported by additional dates, then one possible interpretation would be that the interpopulation variation may reflect a small group of migrant individuals which has diverged from the parent population, but has continued to share a common burial ground. In accordance, Ossenberg states:

> Whenever a small group becomes separated from its parent population, it is less likely to contain a representative sample of the parent population's gene pool. Throughout human history such situations must have occurred over and over again as small bands split off to migrate in search of new hunting territory, or as large groups were virtually wiped out by famine, disease and warfare, leaving only a handful of survivors. Isolation by inhospitable terrain or other factors, with concomitant inbreeding, would tend to perpetuate the differences initiated by drift, contributing significantly to variation (Ossenberg, 1974:16).

Should additional radiocarbon dates support the third premise - the dates are from individuals of the same population being sampled through time - then the observed intrapopulation variation could be explained within a microevolutionary framework. "Microevolutionary changes in inherited characteristics occur through time in response to selection, gene flow (mixture), and genetic drift" (Ossenberg, 1974:16).

Results

However attractive we may find this or any other conjectural account of the temporal distribution of the Gray Site skeletons, the single concrete conclusion of this study is that the Gray Site does not represent a homogeneous population. The results of the cluster analysis and the discriminant analyses indicate the presence of three morphologically distinct groups in the Gray Site skeletal remains. One group is very distinct while the other two groups, although distinct, approach similarity with each other.

represent a homogeneous population. The results of the cluster analysis and the discriminant analyses indicate the presence of three morphologically distinct groups in the Gray Site skeletal remains. One group is very distinct while the other two groups, although distinct, approach similarity with each other.

Implications of This Thesis

The implications of this thesis for future research in human osteology, and for further research on the Gray Site, are twofold. First, the clear and testable results of this study demonstrate the power of metric analysis to discriminate between different morphological groups. In doing so the results substantiate the utility of metric data in the analysis of skeletal biology. Second, by defining the biological parameters of the Gray Site, this thesis has established a testable pattern for further analysis of the Site. The stability of each of the three defined groups of skeletons may now be investigated by researchers in other disciplines, such as archaeology and cultural ecology, and the multi-dimensional techniques available for accurate dating may be used to establish a chronological sequence of events for the Gray Site populations and other Oxbow Culture groups.

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