2009 International Nuclear Atlantic Conference – INAC 2009
Rio de Janeiro, RJ, Brazil, September 27 to October 2, 2009
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR – ABEN
ISBN: 978-85-99141-03-8

PRELIMINARY CHARACTERIZATION OF CERAMICS FROM THE LAGO GRANDE ARCHAEOLOGICAL SITE IN THE CENTRAL AMAZON BY INAA

Roberto Hazenfratz, Casimiro S. Munita, Eduardo G. Neves, Paulo M. S. Oliveira, Rosimeiri G. Toyota

Instituto de Pesquisas Energéticas e Nucleares, IPEN – CNEN/SP
Av. Prof. Lineu Prestes, 2242 – Cidade Universitária – CEP 05508-000
São Paulo – SP – Brasil
robertohm@usp.br

ABSTRACT

The macroscopic characteristics of archaeological ceramics, such as the surface decoration and shape, are used as cultural and chronological indicators of ancient people. The combination of stylistic-typological studies with archaeometric analysis, as provenance studies, has been considered of great importance in Archaeology. The purpose of this paper is to contribute to the understanding of the pre-colonial Amazonian occupations. Inside this context, fifty ceramic fragments from the Lago Grande archaeological site were analyzed by INAA in order to characterize its elemental composition. The results were treated with multivariate statistics: Cluster, Principal Components and Discriminant Analysis. The results obtained by these three methods were compared in an effort to achieve some correlation with the archaeological context. It was stated the existence of two different groups of artifacts. They probably regard to the main ceramic phases found in the site excavation: Paredão and Manacapuru. Once confirmed by other archaeological analyses, these results could corroborate an exchange net among the former inhabitants of Lago Grande and other sites in the neighborhood.

1. INTRODUCTION

The physicochemical characterization of archaeological vestiges has been widely employed in the elucidation of questions regarding the origin of raw material, the methodology of manufacture and the existence of interconnections among human groups, based, for example, on the study of ceramic materials [1]. The implicit basic idea of those studies is that the elemental composition (mainly the trace elements) of each ceramic is an indicative of the raw material used in its production: the clay and the antiplastic [2]. These studies are often considered as provenance studies, correlating the ceramics to their sources.

The compositional analyses of archaeological vestiges have been accomplished under the framework of a discipline called Archaeometry [3], which appeared as a systematization of an interdisciplinary area of studies that links the natural sciences to the conservation, restoration and study of the cultural heritage [4].

One of the main focus of Archaeometry has been the study of ceramics that, due to their intense production by human groups in the past and their resistance to adverse environmental conditions, has been found in significant quantities in the majority of the archaeological sites dating since the Neolithic. For this reason, they play a central role in the study of sites, regions and periods. The main objective in the ceramic studies is to reconstruct its life cycle, since the production (identifying centers of manufacture, source of raw materials, superficial treatment, burning process, among others) until the final usage, correlating this life cycle to the behavior of the groups involved, in an attempt of reconstructing their past inside the archaeological context in which the ceramics were produced, distributed and used [5,6].

The macroscopic characteristics of ceramics, such as the surface decoration and shape, are used as cultural and chronological indicators. The combination of stylistic-typological with archaeometric analysis has been considered of great importance in Archaeology [7].

2. THE ARCHAEOLOGICAL ISSUE

2.1. The Study Importance

Our knowledge about the pre-colonial occupation of the Amazon region is still inversely proportional to its dimensions. Until recently, the archaeological research in the South America has been greatly focused on the Andean cultures. The reports written by the first European travellers mention the existence of complex and densely populated civilizations, contrasting with the current ethnographic picture, where we can observe sparse occupations with low demographic density, based on structures of age and gender. Those contrasts stimulated an intense discussion in the archaeological community, whose interpretations about the organization of the pre-colonial indigenous populations can be generically classified in two distinct lines of interpretation [8].

The first line is characterized by the environmental determinism, which considers the development of human societies as a direct answer to environmental problems in order to guarantee their survival. In this manner, the followers of this line believe to be improbable the existence of complex human organizations in the rain forest, due to the natural limitations that would stimulate a great mobility in their inhabitants, avoiding the demographic growth and preventing the development of social and politically stratified organizations.

The second line is a critical one, which tries to relativise the role of environmental difficulties as a limiting factor for the emergence of complex societies. The combination of fishing, hunting and collecting in the *várzea* areas would complement alternative forms of agriculture, as the *coivara*, guaranteeing the subsistence of huge human groups. The historical rupture regarding the disappearance of those complex societies would be related to the contact with the Europeans, that brought diseases, war and slavery to the indigenous people [8,9].

2.2 Area of Study

The Lago Grande archaeological site is located in the confluence region of the Negro and Solimões rivers. The Solimões River has white waters with large areas of *várzea*. Its dense and muddy aspect is due to the sediments brought since the nascent, in the Andes mountain range [10]. The Negro river has black waters that have few nutrients due to its high acidity and low mineral content, depositing sandy sediments on its margins, forming extensive beaches of white sand, interspersed by the *igapó* forest.

The confluence region is formed by hills and mounts, crossed seasonally by *igarapés*. The Amazon forest is the original vegetation of the region. The soil has acid pH and low agricultural capacity, in general.

The ceramic material found in this site is related mainly to the Paredão ceramic phase, from the Incised Rim tradition. Ceramics from the Manacapuru phase, related to the same tradition, were also found in a lower proportion. It was suggested that the latter had been the result of exchanges among the site inhabitants, whose ceramic cultural expression is regarded as the Paredão phase, and other tribes related to the Manacapuru phase [10].

Figure 1: Map of the confluence region of Negro and Solimões rivers in the central Amazon. Font: [9]

3. EXPERIMENTAL PROCEDURE

The archeological material was provided by the Museum of Archaeology and Ethnology of the University of São Paulo (MAE-USP). The artifacts were collected in the scope of the Central Amazon Program (Programa Amazônia Central-PAC) in an effort to understand the pre-colonial occupation of that region.

Fifty ceramic fragments were washed with Milli-Q deionized water. The external surface was removed with a fine bristle brush. After this procedure, the samples were placed in an oven at 104 ºC during 30 minutes. Then, holes were made on the samples with a tungsten carbide rotary file, attached to a variable speed drill. Around 500 mg of powdered sample is obtained from 3 up to 5 holes on the internal surface of the ceramic fragment, preventing the drill from crossing over the walls. This powder is then collected, dried for 24 hours in an oven at 104 ºC and stored in a desiccator [11].

For the irradiation, 100 mg of each sample were weighted in polyethylene involucres and sealed with sealing iron. Each involucre was wrapped in aluminum foil. Groups of 7 ceramic powdered samples and two reference materials were wrapped in aluminum foil. It was used *Standard Reference Material – NIST-SRM 1633b* as standard for analysis and *IAEA Soil 7* for the analytical quality control. The samples were irradiated in the swimming pool research reactor IEA - R1 of IPEN - CNEN/SP, at a thermal neutron flux of $5.10\ n.cm^{2}.s^{-1}$ during 1 hour.

The gamma-ray spectrometry was carried out with a hyperpure germanium detector (model GX 2519 from Canberra), with a resolution of 1.90 keV at the 1332 keV gamma peak of ^{60}Co. The spectra were collected via a Canberra S-100 MCA plate with 8192 channels. The software Genie-2000 NAA Processing Procedure, developed by Canberra, was used to obtain and analyze the gamma-ray spectra.

Two measurement series were carried out. The elements As, K, La, Lu, Na, Nd, Sb, Sm, U e Yb were measured after 7 days of decay. The elements Ba, Ce, Co, Cr, Cs, Eu, Fe, Hf, Rb, Sc, Ta, Tb, Th e Zn were measured after 25-30 days of decay [12].

4. DATA TREATMENT AND INTERPRETATION

The elements eliminated from analysis were: As, K, Nd, Sm, Co, Zn, Rb, Sb, Ba and Ta. The main reasons for the removal were the bad analytical precision, assessed by the quality control, as well as contamination during the experimental procedure.

It is highly recommended to rescale the data before the multivariate analysis, as Principal Component Analysis and Cluster Analysis. The results of concentrations were normalized by the logarithmical transformation on base 10 to compensate the differences in the magnitude of the elemental concentrations which are in percentage from the ones in trace level. It is an usual procedure in Archaeometry before the multivariate statistical analysis and is justified by the fact that the normal distribution of elemental concentrations in the soil is logarithmic [13,14]. Table 1 shows the concentration results for the Lago Grande archaeological site. The errors are not shown due to the restriction of space.

Table 1: Elemental concentration data for ceramics from Lago Grande archaeological site in $\mu g.g^{-1}$, unless indicated.

Sample	Na (%)	Lu	U	Yb	La	Th	Cr	Cs	Sc	Fe (%)	Eu	Ce	Hf	Tb
1	0.30	0.60	4.40	3.70	52.30	15.50	74.10	1.30	19.00	4.50	1.70	98.30	5.70	0.60
2	0.20	0.50	5.20	3.00	44.60	13.50	66.50	3.90	17.10	4.70	1.30	83.00	4.70	1.20
3	0.30	0.30	2.40	2.00	31.00	9.40	52.00	9.30	11.80	3.10	0.90	57.50	3.40	0.90
4	0.50	0.60	3.80	3.10	40.00	12.40	58.70	4.20	15.40	46.50	1.30	70.00	6.80	1.20
5	0.10	0.70	3.70	3.70	61.00	16.70	80.80	1.50	17.80	4.10	2.00	113.50	7.10	1.10
6	0.20	0.30	2.60	2.40	33.70	11.30	46.70	11.00	12.20	3.10	1.00	70.60	4.90	0.30
7	0.20	0.40	4.10	2.20	40.00	13.70	63.00	13.00	15.50	4.10	1.20	77.00	6.50	0.95
8	0.40	0.40	3.40	2.60	33.50	12.10	68.20	6.10	14.70	4.60	0.90	62.50	5.60	0.50
9	0.04	0.40	2.80	2.60	24.90	15.10	36.40	6.80	7.60	1.30	0.70	47.60	17.30	0.30
10	0.08	0.50	5.30	3.10	48.00	14.10	61.10	9.60	11.80	1.90	1.30	119.90	11.10	1.20
11	0.30	0.40	3.20	2.60	38.10	14.60	71.80	12.90	16.90	4.00	1.10	79.30	4.80	0.70
12	0.30	0.40	3.30	2.40	37.80	12.10	53.50	13.70	13.70	2.90	1.20	71.70	4.50	0.80
13	0.40	0.40	3.60	2.60	46.30	14.40	69.20	13.50	16.90	3.30	1.50	91.10	5.20	0.90
14	0.30	0.40	8.70	2.90	41.30	13.10	67.50	5.20	15.10	3.10	1.30	79.20	5.00	0.70
15	0.05	0.40	3.70	2.00	34.10	14.20	59.30	13.70	13.60	4.20	0.80	64.00	9.00	0.30
16	0.20	0.50	4.20	2.80	41.90	12.50	60.50	6.00	14.50	3.30	1.50	80.10	3.90	1.10
17	0.25	0.40	5.60	3.20	44.60	14.60	65.50	7.90	16.30	2.80	1.30	82.70	5.00	0.77
18	0.06	0.40	3.50	2.20	35.60	15.40	59.80	16.00	12.20	1.90	0.80	65.00	11.90	0.42
19	0.01	0.40	4.00	2.90	36.20	13.50	65.40	3.90	11.60	3.50	0.65	64.80	8.90	0.77
20	0.30	0.40	2.60	2.80	38.00	12.00	57.00	8.00	14.50	3.40	1.40	73.50	3.90	0.90
21	0.05	0.40	4.50	2.60	44.50	15.00	62.60	11.60	13.70	2.90	1.00	78.70	6.70	0.50
22	0.30	0.60	4.20	3.30	46.80	14.30	72.10	7.00	17.60	3.90	1.50	88.60	4.80	1.10
23	0.04	0.30	2.80	2.20	30.00	7.60	38.60	6.80	9.50	2.20	0.80	57.60	4.00	0.60
24	0.50	0.50	3.80	3.30	43.30	14.40	65.30	8.50	16.60	3.50	1.60	87.40	5.80	0.90

Table 1: Continued

Sample	Na (%)	Lu	U	Yb	La	Th	Cr	Cs	Sc	Fe (%)	Eu	Ce	Hf	Tb
25	0.05	0.30	2.60	2.10	30.10	11.20	48.70	13.10	11.40	2.20	0.80	54.30	4.10	0.77
26	0.60	0.60	4.80	3.70	42.41	15.50	77.00	11.00	18.20	3.60	1.50	111.70	6.80	0.80
27	0.40	0.40	3.80	3.10	43.00	13.10	68.50	8.00	16.80	3.90	1.40	79.50	5.20	1.20
28	0.03	0.40	3.40	2.50	39.50	12.60	62.00	6.30	14.20	3.20	0.90	70.80	8.30	0.61
29	0.14	0.50	3.70	3.80	57.40	16.70	87.70	4.60	19.80	3.90	1.80	114.00	6.40	0.90
30	0.04	0.50	3.00	2.70	33.50	15.00	51.00	8.00	10.20	2.80	0.90	57.00	9.60	0.40
31	0.30	0.50	3.50	2.80	35.50	12.30	58.40	12.30	12.90	2.90	1.02	65.00	9.10	0.70
32	0.05	0.50	3.90	2.70	54.80	14.60	56.40	7.80	11.00	3.10	1.60	81.30	9.70	0.80
33	0.20	0.50	4.30	3.30	43.60	15.70	73.10	9.90	18.00	4.80	1.40	91.70	9.00	0.80
34	0.20	0.60	4.60	3.50	53.80	15.10	71.00	9.90	17.00	3.90	1.70	103.80	7.50	1.20
35	0.15	0.50	4.30	3.10	44.10	15.50	69.90	10.70	15.80	3.90	1.40	86.60	7.70	1.00
36	0.11	0.50	3.00	2.80	35.10	11.80	54.30	6.70	11.70	2.80	1.10	61.20	7.40	0.90
37	0.04	0.30	3.50	2.40	38.10	11.80	57.00	11.30	13.00	2.50	0.98	70.30	4.70	0.40
38	0.20	0.50	3.90	3.20	41.60	14.90	70.00	9.10	16.20	3.80	1.30	81.30	7.20	0.40
39	0.20	0.50	4.80	3.40	46.40	15.40	64.80	11.20	15.80	4.50	1.60	88.30	6.00	0.90
40	0.15	0.40	3.40	2.70	37.60	12.10	54.80	12.10	14.00	3.50	1.30	69.90	3.40	0.50
41	0.06	0.50	3.90	2.80	41.30	14.20	68.10	12.60	15.00	3.20	1.00	77.30	8.90	0.50
42	0.20	0.60	4.70	3.50	41.30	14.40	69.80	7.60	15.60	4.10	1.30	77.50	8.00	0.80
43	0.21	0.70	5.60	4.60	52.10	12.90	60.50	12.20	12.80	2.80	0.90	77.20	9.30	0.70
44	0.10	0.50	3.30	3.20	53.10	15.10	71.00	9.20	16.60	3.50	1.70	95.60	6.30	0.50
45	0.13	0.50	4.00	3.20	45.80	11.50	64.00	9.50	11.40	3.40	1.40	81.60	4.50	0.77
46	0.10	0.60	3.80	3.80	55.30	14.00	71.90	9.10	16.70	3.70	1.80	107.90	5.40	0.70
47	0.21	0.60	4.70	4.00	53.40	18.60	84.80	16.20	18.30	4.70	1.60	97.00	11.20	1.10
48	0.20	0.50	5.20	3.60	58.50	14.90	83.10	12.30	17.40	4.10	2.00	110.30	5.20	0.60
49	0.42	0.50	4.80	3.30	39.40	13.30	73.50	9.50	14.30	3.20	1.60	76.80	10.80	0.90
50	0.11	0.50	4.10	3.40	42.80	14.40	72.90	10.90	15.50	4.10	1.40	78.90	8.40	0.80

After this data pre-treatment, an outlier removal procedure was carried out, followed by a multivariate statistical analysis.

4.1 Outliers Removal

Everitt [15] notes that many data clustering algorithms are sensitive to outliers and it would be convenient to try to identify and remove them before analysis. The procedure employed to analyze the existence of outliers was the Wilk´s multivariate outlier test. It is based on the Mahalanobis distance and supposes normal distribution for the data.

The quadratic Mahalanobis distance matrix between each sample coordinates vector and the mean vector was calculated. The values were compared with the critical value of Wilks [16]:

$$D_{crit} = \frac{p(n-1)^2 F_{p,n-p-1,\alpha/n}}{n\left(n-p-1+pF_{p,n-p-1,\alpha/n}\right)} \quad \textbf{(1)}$$

where,

n is the number of samples
p is the number of variables
F is the statistic regarding the Snedecor distribution
α is the level of significance adopted.

The quadratic distances higher than the critical value are indicative of outliers, according to this method. The confidence level α applied to the calculation of λ was 95%.

By this procedure, 7 outliers were found in the data set, corresponding to the samples: 4, 9, 10, 19, 26, 32 and 43.

4.2 Multivariate Statistical Analysis

Firstly, a cluster analysis was carried out to observe if a plausible data partition is possible. For the first grouping procedure, the Ward´s method was employed due to its tendency to form groups with high internal homogeneity and because it takes account of the cluster structure [17]. The allocation of one element in a group by Ward´s method is performed so that a measure of internal homogeneity is minimized. This measure is based on the partition of the total sum of squares related to a variance analysis [18]. The similarity measure employed was the squared Euclidean distances matrix between the observations. The dendrogram is showed in Figure 2.

Using the criterion of cutting the tree on the point where the higher linkage distance variation is observed, we could establish the existence of two clusters. Nevertheless, as a higher variation in the linkage distance is a necessary but not a sufficient condition to cut a dendrogram, it is convenient to establish a correlation of this procedure with the expectations held considering the archaeological background of the present analysis. In this manner, a tree cut with the formation of two groups can be correlated to the two ceramic phases present in Lago Grande, Paredão and Manacapuru. Furthermore, the smallest group might indicate the Manacapuru phase, present in a lower proportion, as expected by the archaeological knowledge. The biggest group might represent the Paredão phase, the proper cultural expression from Lago Grande archaeological site [10]. The formation of these two groups would indicate a different source of the raw materials, reflecting in different composition patterns.

The Ward's method is known to produce spherical clusters of similar size. The Average Linkage method is another approach used frequently in archaeological pottery studies and also takes the cluster structure into account. The Average Linkage method uses the average of distances among the elements of each group as the measure of distance between groups [18]:

$$d[G_1, G_2] = \sum_{i \in G_1} \sum_{k \in G_2} \frac{d_{ik}}{g_1 g_2} \qquad \textbf{(2)}$$

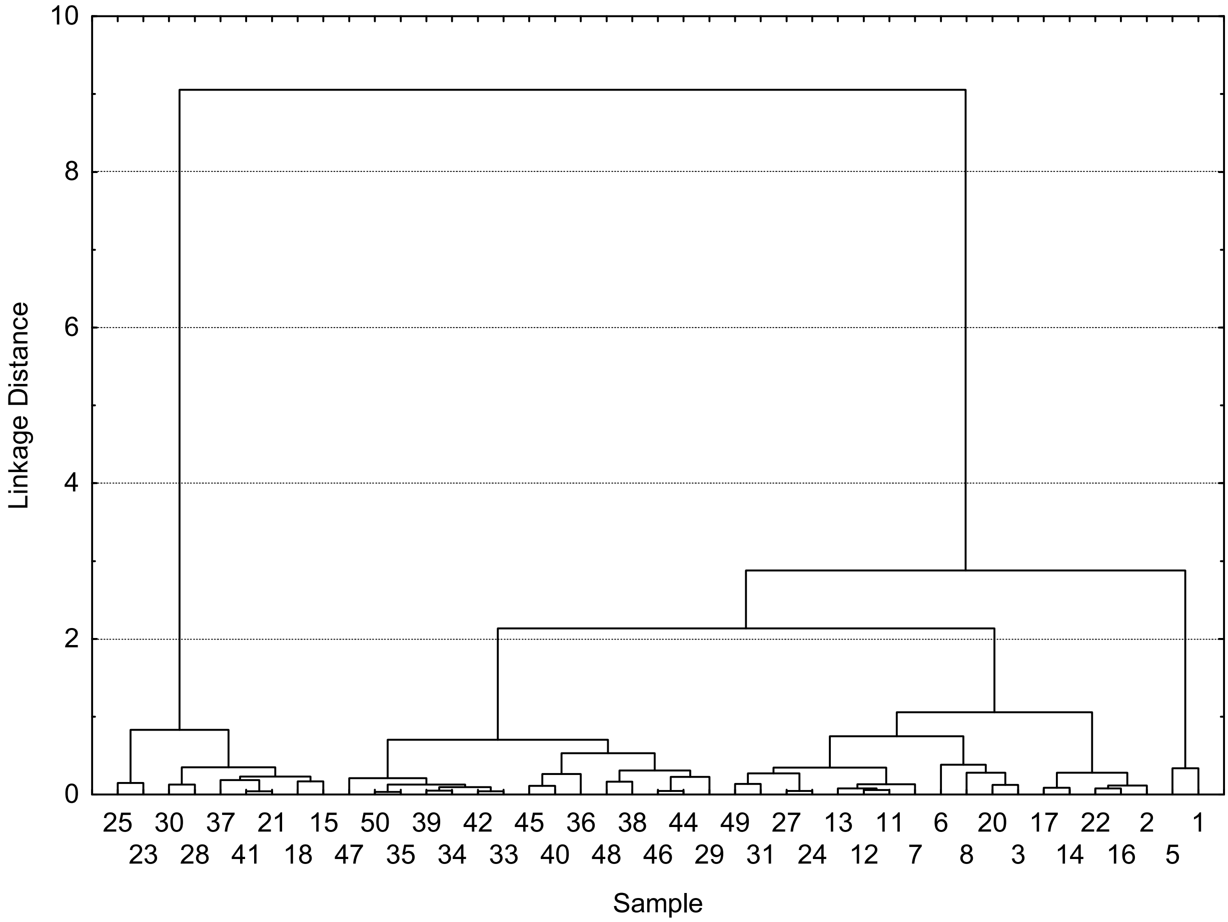

Figure 2: The cluster analysis dendrogram by Ward's method for the data from Lago Grande archaeological site.

The comparison of the latter two methods of clustering is advised by Baxter [17]. So, a cluster analysis by the Average Linkage method using the Euclidian distances was carried out for comparison. The dendrogram is showed in Figure 3. It can be seen that the highest variation for the linkage distance is observed for the amalgamation of the two biggest groups, as the samples 1 and 5 are, probably, according to this method, considered outliers. Using this criterion and the archaeological background as stated previously, it would be chosen 2 groups of different artifacts, as by the Ward´s method.

Hierarchical cluster analyses can impose unwarranted structure on a set of data. Once an object is placed to a group, it remains there until the end of the clustering algorithm. The placement of individuals inside groups is not necessarily optimal. There is no basis in general to expect a hierarchical structure to obtain, and k-means method can improve the classification according to the clustering criterion used. So, it is advisable to verify the existence of any problem related to a bad classification of samples. For this purpose, a K-means clustering procedure was carried out.

The K-means is a partition method where the number of groups must be chosen a priori in order to reduce the partition possibilities, making the method more efficient in terms of the computing effort needed. The criterion of the grouping quality used by K-means is based on the partition of the total sum of squares in a variance analysis, as employed in the Ward's method. One partition will be considered optimum if it minimizes the partition sum of squares.

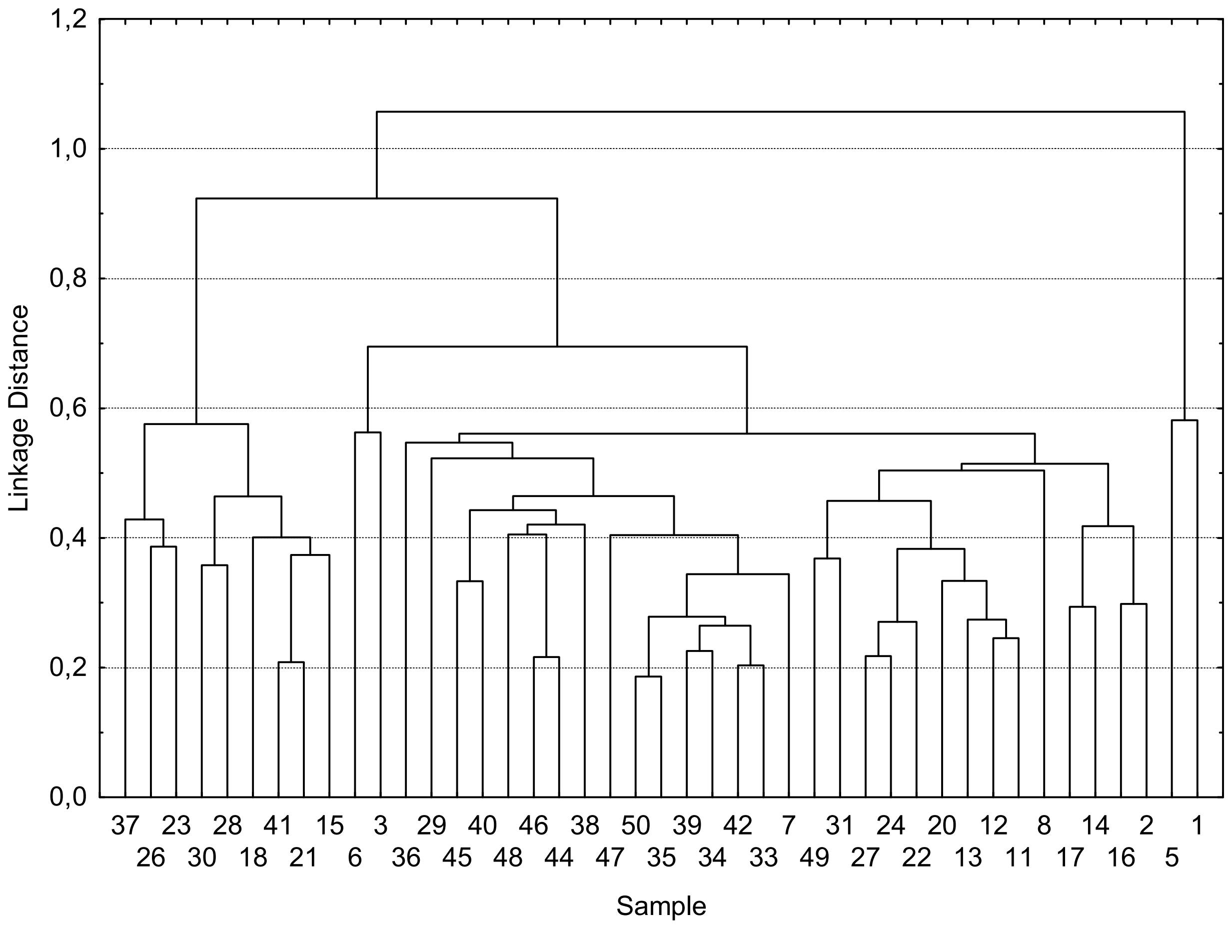

Figure 3: The cluster analysis dendrogram by the Average Linkage method for the data from Lago Grande archaeological site.

The method of K-means was applied several times to start the partitioning process from different random objects, considering the existence of two clusters. Table 2 summarizes the group assigned to each object. It should be emphasized that, as the objects 1 and 5 in the Figure 3 were not considered as outliers until further analysis of the groups are made, they were manually assigned to the group 2.

As can be seen by Table 2, the hierarchical methods Ward and Average Linkage and the partitioning method of K-means assign the objects to the same groups, which can increase our belief in the classification obtained.

After the clustering procedure, a principal component analysis (PCA) was carried out in order to verify the data structure. Be x the vector of the original variables $x^T = (X_1,...X_{14})$, with $Cov(x) = \Sigma$. The principal components will be the following non-correlated linear combinations, whose variances are the highest possible:

$$Y_i = \underline{l}_i^T \underline{x} \quad \text{with i=1…14} \qquad \textbf{(3)}$$

The mathematical modeling is detailed in [18].

The purpose of a PCA, in the present case, is to confirm a possible multivariate data division into groups, through a spatial visualization projected on the first two components of the 14-dimensional space regarding the vectors of observations. For this analysis, the first two components represent 69% of the total system variance. For the calculations it was used the covariance matrix instead of the correlation matrix. It was observed that with the latter, the results are more difficult to interpret, a fact that is sometimes also reported in the literature [17]. One possible reason to that is the dilution of the differences with respect to those variables that best discriminate the clusters. The scores of the objects related to the first two principal components are represented in Figure 4.

Table 2: Group assignment comparison between 3 methods of clustering

Sample	Group			Sample	Group		
	Ward	Average Linkage	K-means		Ward	Average Linkage	K-means
1	2	2	2	28	1	1	1
2	2	2	2	29	2	2	2
3	2	2	2	30	1	1	1
5	2	2	2	31	2	2	2
6	2	2	2	33	2	2	2
7	2	2	2	34	2	2	2
8	2	2	2	35	2	2	2
11	2	2	2	36	2	2	2
12	2	2	2	37	1	1	1
13	2	2	2	38	2	2	2
14	2	2	2	39	2	2	2
15	1	1	1	40	2	2	2
16	2	2	2	41	1	1	1
17	2	2	2	42	2	2	2
18	1	1	1	44	2	2	2
20	2	2	2	45	2	2	2
21	1	1	1	46	2	2	2
22	2	2	2	47	2	2	2
23	1	1	1	48	2	2	2
24	2	2	2	49	2	2	2
25	1	1	1	50	2	2	2
27	2	2	2				

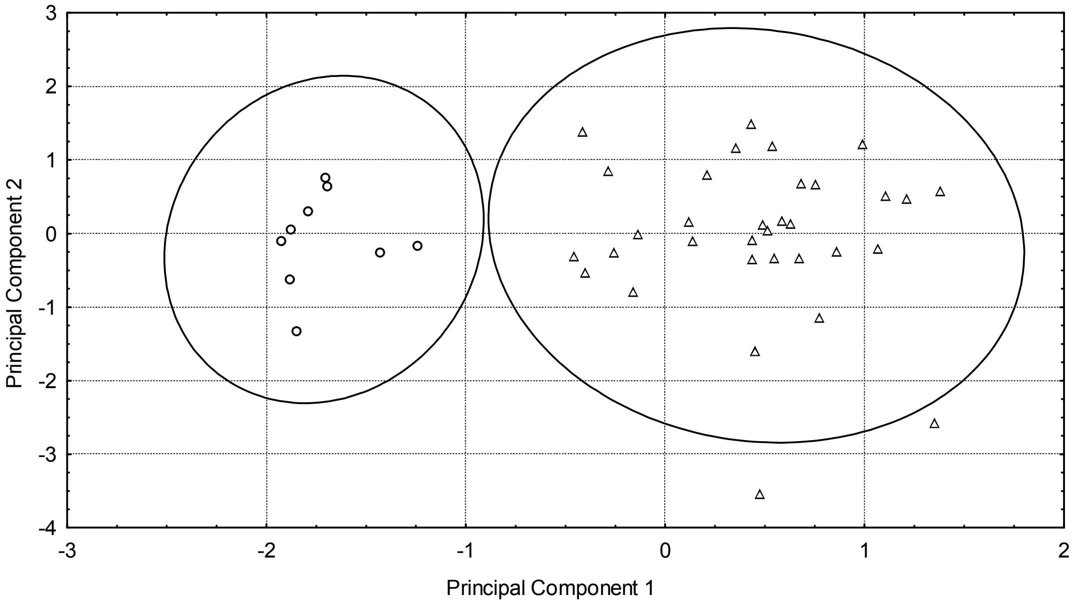

Figure 4: Two first components scores in a PCA for the data from Lago Grande archaeological site. The ellipses represent the confidence level of 95%.

In Figure 4, it can be seen the probable existence of two groups for the data, represented by the respective ellipses limiting the region of 95% of confidence to find the data. It confirms that the tree cut for two clusters is probably a plausible assumption.

For comparison with the cluster procedures, a discriminant analysis was carried out in order to assess how reasonable was the classification of objects by the clustering algorithms. The standardized canonical discriminant functions were calculated. Firstly, it was admitted the existence of two groups. A visualization of the groups against the discriminant values for the data is showed in Figure 5.

By the Figure 5, it is possible to verify that the smallest group presents higher values for the discriminant function and the biggest one presents lower values. Problems of misclassification by cluster analysis were not observed.

Furthermore, it was admitted the existence of three groups, in order to verify if it would be plausible a further data partitioning, as well as to verify the classification given by the cluster analysis. The bi-plot of the two discriminant functions is presented in Figure 6.

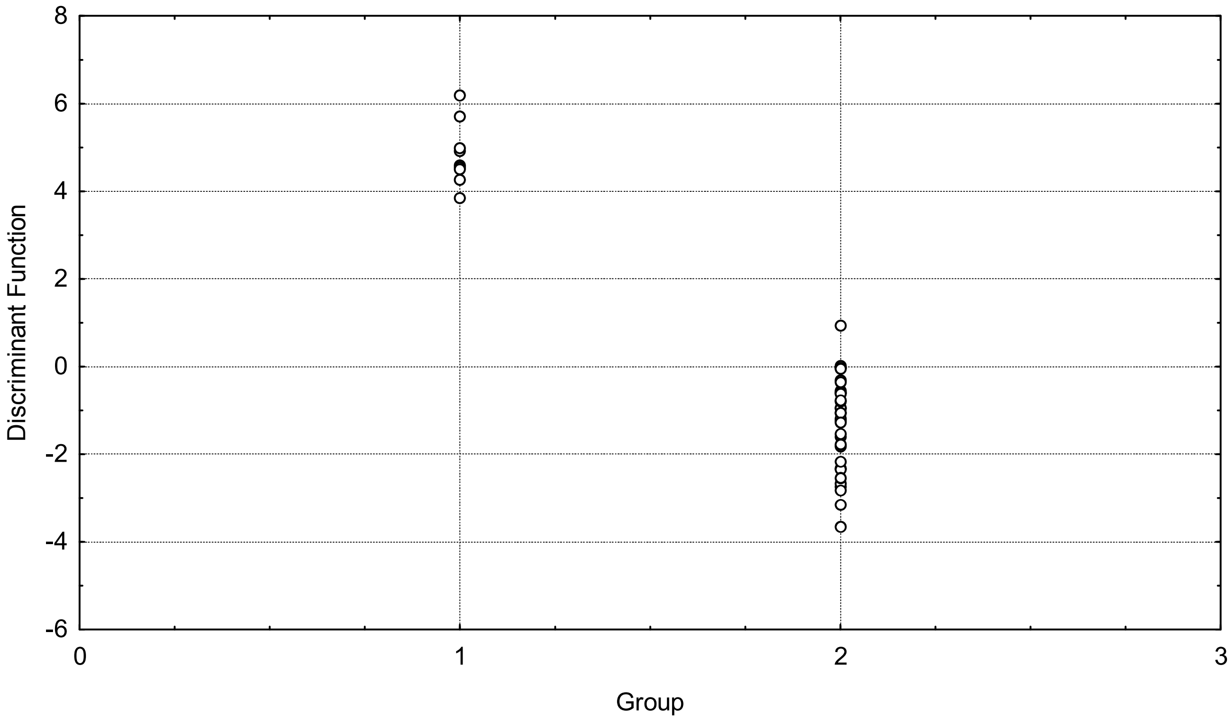

Figure 5: Discriminant analysis admitting 2 groups for the data from Lago Grande archaeological site.

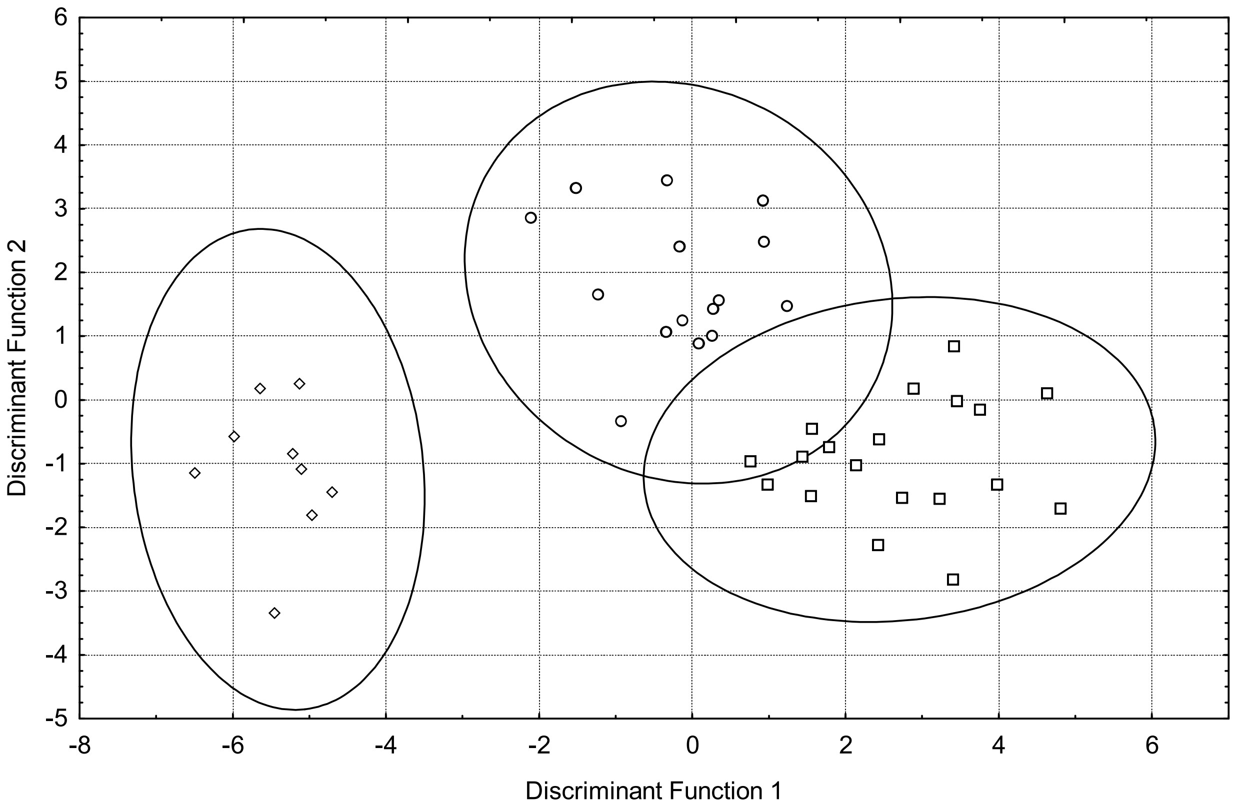

Figure 6: Discriminant analysis admitting 3 groups for the data from Lago Grande archaeological site. The ellipses represent the confidence level of 95%.

By Figure 6, it would be possible to admit the existence of 3 groups. In order to verify the samples classification quality by the cluster analysis (Ward´s method), a cross-validation procedure was performed in Minitab. It was assessed that 93% of the classifications coincide between discriminant and cluster analysis. Anyway, it is important to observe that the smallest group remains unchangeable in both discriminant analysis admitting 2 and 3 groups, and it is also more differentiable, because its ellipse of 95% of confidence does not touch the others.

One point deserves to be highlighted here. The linear discriminant analysis lies upon the hypothesis that the covariance matrices for the groups are similar. As can be observed by Figure 4, this hypothesis could be illegitimate. It is convenient to assess a formal test on the hypothesis in order to verify how adequate is the linear discriminant analysis for the Lago Grande data. For this reason the question of the three possible groups will not be problematized in the scope of this paper.

5. CONCLUSION

Until the present moment, by the multivariate statistical analysis employed, the existence of two different groups of artifacts will be considered, which are probably correlated to the main ceramic phases found in the Lago Grande archaeological site. One is Paredão phase, the proper artistic style developed by the former inhabitants of Lago Grande. In a lower proportion, there is Manacapuru, a ceramic phase present in some sites in the same region, as Osvaldo archaeological site. Furthermore, the compositional difference between the artifacts would indicate the existence of two different clay sources for each group. The statistical analysis will be correlated to stylistic studies carried out by archaeologists. If the results be confirmed, they might indicate an exchange net between Lago Grande and other archaeological sites in the central Amazon.

ACKNOWLEDGMENTS

The present work was realized with the support from "Conselho Nacional de Desenvolvimento Científico e Tecnológico" – CNPq – Brazil. Process Number: 134116/2009-7.

REFERENCES

[1] S. PAVIA, The determination of brick provenance and technology using analytical techniques from the physical sciences, *Archaeometry*, **47**, pp. 201-218 (2006).
[2] C. S. MUNITA, Contribuição da análise por ativação com nêutrons a estudos arqueométricos: estudo de caso, *Canindé*, **6**, pp. 159-181 (2005).
[3] R. J. SPEAKMAN, M. D. GLASCOCK, Acknowledging fifty years of neutron activation analysis in Archaelogy, *Archaeometry*, **49**, pp. 179-183 (2007).
[4] M. MARTINI, Physics Methods in Archaeometry: Proceedings of the International School of Physics "Enrico Fermi", Villa Monastero (2003).
[5] M. S. TITE, Ceramic production, provenance and use – a review, *Archaeometry*, **50**, pp. 216-231, (2007).

[6] M. D. GLASCOCK, H. NEFF, K. J. VAUGHN, Instrumental Neutron Activation Analysis and Multivariate Statistics for Pottery Provenance, *Hyperfine Interactions*, **154**, pp. 95-105 (2004).
[7] C. C. LAMBERG-KARLOVSKY, *Archaeological Thought in America*, Cambridge University Press (1991).
[8] J. S. MACHADO, *Dos artefatos às aldeias:* os vestígios arqueológicos no entendimento das formas de organização social da Amazônia, *Revista de Antropologia*, **49(2)**, pp. 755-786 (2006).
[9] R. C. PORTOCARRERO, *A variabilidade espacial no sítio Osvaldo. Estudo de um assentamento da tradição barrancóide na Amazônia centra,* Universidade de São Paulo, São Paulo (2006).
[10] P. B. DONATTI, *A ocupação pré-colonial da área do Lago Grande, Iranduba, AM.,* Universidade de São Paulo, São Paulo (2003).
[11] C. S. MUNITA, R. P. PAIVA, M. A. ALVES, P. M. S. OLIVEIRA, E. F. MOMOSE, Provenance study of archaeological ceramic, *J. Trace Microprobe Techniques,* **21**, pp. 697-695 (2003).
[12] C. S. MUNITA, Contribuição da análise por ativação com nêutrons a estudos arqueométricos: estudo de caso, *Canindé***, 6**, pp. 159-181 (2005).
[13] T. BEIER, H. MOMMSEN, Modified Mahalanobis filters for grouping pottery by chemical composition. *Archaeometry,* **36**, pp. 287-306 (1994).
[14] E. V. SAYRE, Brookhaven Procedures for Statistical Analyses of Multivariate Archaeometric Data, *Brookhaven National Laboratory Report BNL-21693*, New York (1975).
[15] B. S. EVERITT, *Cluster Analysis,* 2nd ed,, Heinemann Educational Books, London (1980).
[16] P. M. S. OLIVEIRA, *Influência do Valor Crítico na Detecção de Valores Discrepantes em Arqueometria***.** 10º SEAGRO, Lavras (2003).
[17] M. J. BAXTER, *Exploratory Multivariate Analysis in Archaeology,* Edinburgh Univesity Press (1994).
[18] L. P. BARROSO, R. ARTES**,** *Minicurso Análise Multivariada,* Lavras, From 07th to 11th July (2003).