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EVALUATING THE VARIABILITY OF SOUTHWESTERN CERAMICS WITH X-RAY FLUORESCENCE

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Our assessment of prehistoric trade in ceramics depends on our ability to identify and distinguish different sources of manufacture. For the American Southwest, archaeologists have proposed various models of ceramic manufacture and exchange. Until recently, conflicting hypotheses were tested mainly on the basis of petrographic analysis of nonplastic tempering materials. We have extended these analyses to include x-ray fluorescence (XRF). XRF provides a fast and inexpensive means of analyzing large numbers of samples. Since 1982, approximately 500 prehistoric sherds and 40 prepared clay and mineral samples have been examined with XRF. Multivariate statistical techniques have been applied to help identify groupings of samples with possible archaeological significance.

Evaluating the Variability of Southwestern Ceramics with X-ray Fluorescence

For the period after about 100 B.C., the Southwest has been broadly divided into four culturally distinct regions: the Anasazi, Mogollon, Hohokam, and prehistoric Yuman culture areas. Definition and identification of these culture areas has been based largely on extant material culture, particularly pottery and house-types. Pottery is especially important in archaeological investigations because it is unquestionably man-made and it is virtually indestructible in the dry Southwestern climate. The pottery produced by the inhabitants of the Southwest was also highly variable through time and across space, so that over 900 distinct ceramic types have been defined for Southwestern culture groups. And since potters tended to use materials available in the vicinity of their villages, materials analysis of plastic and non-plastic constituents of ceramics can aid in evaluating where pottery was made. For these reasons, ceramics have come to occupy an important place in studies of Southwestern prehistory.

In performing materials analysis, archaeologists in the Southwest have been primarily concerned with addressing two problem areas: the locus of production and mode of production of the ceramics. Research concerned with locus of production seeks to establish the origin for pottery or materials used in making the pottery, and aids in identifying ceramics made elsewhere and brought into a site as opposed to those locally manufactured. Research concerned with the mode of production of ceramics attempts to differentiate pottery produced on a site level from that produced by manufacturing centers.

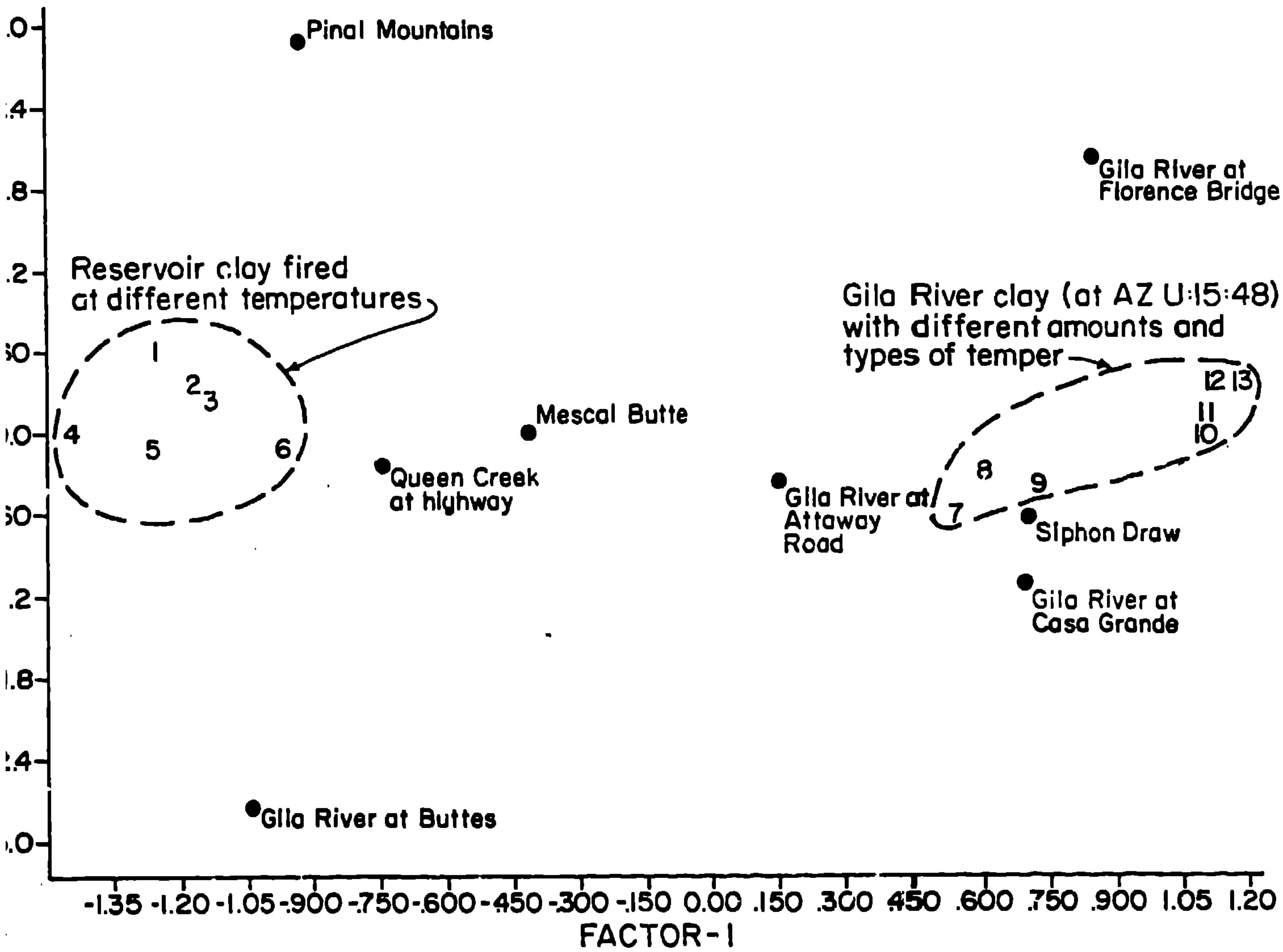
The research described here involved the investigation of both locus of production and mode of production for ceramics from the Hohokam area of southern Arizona (Crown 1984). Ongoing research performed at the Los Alamos National Laboratory using material from the collections of the Arizona State Museum of the University of Arizona has involved the analysis of over 500 prehistoric and modern ceramic samples to date through energy-dispersive x-ray fluoresence (XRF). Prior to describing a portion of the research results, the general methodology used will be discussed.

Experimental Procedure and Data Reduction

Sherds were prepared for analysis by first breaking an edge to expose an uncontaminated portion of the interior paste. If large temper inclusions were visible the sample was rebroken, since our analysis was intended to be of the homogeneous mixture of temper and plastic materials. When a reasonably flat surface with uniform visual appearance was obtained, the sherd was clamped in a vice and placed before the source-detector system with the broken surface positioned roughly perpendicular to the axis. Each sample was then counted for 10 minutes. The XRF results were displayed as 1024-channel spectra spanning the energy range from zero to 20 keV. After each measurement the raw spectral data were stored or floppy disc for later reduction.

A Cd-109 annular ring source was used to excite the fluorescent radiation. Typical spectra included six elements: calcium, iron, rubidium, strontium, yttrium, and zirconium. Titanium, manganese, copper, zinc, and lead were occasionally observed, but the signals were small and these element concentrations were not considered in the formal analysis.

The object of this study was to find whatever systematic differences there might be in the element concentrations of sherds recovered from the different sites. Because the conclusions of this work depended mainly on qualitative differences in sherd compositions, it was not necessary to derive absolute element concentrations from the data. It was sufficient to consider variations in the patterns, or relative peak intensities in the fluorescent spectra. Observed signals were not compared directly because nonuniformities in sherd thicknesses and differences in sample positioning during the analyses can affect these data significantly. However, meaningful comparisons can be made after the peak intensities have been normalized. To do this we expressed each intensity as the fraction of the total integrated peak heights recorded for the six elements. The data, expressed in this form, were then analyzed using a stepwise discriminant function program and plotted. Non-normalized data were also used for principal components analysis, and the resulting factors plotted (Dixon and others 1981).



1 61 clay, 1100°
2 61 clay, 500°
3 61 clay, 250°
4 61 clay, 900°
5 61 clay, 700°
6 Queen Creek at AZ U:15:61
7 Gila River clay with Jemez sand
8 15% phyllite and Gila River clay
9 10% phyllite and Gila River clay
10 Pinal schist and Gila River clay, Queen Creek phyllite and Gila River clay
11 Gila River clay at AZ U:15:48
12 20% phyllite in Gila River clay, Pinal phyllite temper in Gila River clay
13 Mescal schist temper in Gila River clay

Figure 1. Plot of Factors 1 and 2 for experimental clay samples principal components analysis.

Prior to performing the analyses, we considered it important to evaluate the possible effects different temper might have had on the XRF results given identical clays. In order to examine this problem, a single clay source was analyzed by itself and with five distinct tempering materials. In addition, in order to test for a threshold at which temper amounts would affect the results, measured quantities of temper were added to this clay to obtain proportions of 10, 15, and 20 percent temper to clay. All samples were formed into briquettes and fired at 700 degrees centigrade for thirty minutes. For control ten briquettes of untempered clay taken from sources in the Hohokam area were analyzed, in addition to five briquettes of a single clay source fired at 200 degree intervals. These last samples were run in order to examine possible changes in relative frequencies of elements caused by differences in firing temperatures. A plot (Figure 1) of the results of a principal components analysis of the experimental briquettes reveals that temper had little effect on the relative proportions of the elements recorded and that sherds with the same clays cluster together regardless of the temper or firing temperature.

Evaluating Locus of Production of Plain Ware Ceramics

The Hohokam occupied the southern Arizona desert between approximately 100 B.C. and A.D. 1450. During most of this time period, they lived in villages with houses built partially underground and constructed of wattle and daub. During the last 300 years of their occupation of the area, they began to build above ground structures of adobe. They are probably best known for having constructed ball courts, large platform mounds, the Casa Grande, and complex irrigation systems.

Prior to our research, the only materials analysis of Hohokam ceramics had been several small-scale petrographic studies (Gladwin 1937; Loomis 1980; Rose and Fournier 1981; Hepburn 1984), and a single inconclusive x-ray diffraction study of five sherds (Doyel 1974). The XRF analysis was designed to address specific questions concerning Hohokam pottery production and exchange that had not been answered through other means.

An example of the use of XRF in exploring locus of production of Hohokam ceramics comes from our study of the plain ware ceramics produced by these people between A.D. 1050 - 1200. In assessing locus of production, archaeologists use the "criterion of abundance" postulate that states that the pottery found in greatest abundance at a site or in a region is of local manufacture; while that occurring in low frequency is of nonlocal manufacture (Bishop, Rands, and Holley 1982). Cooking and storage vessels found in southern Arizona are undecorated "plain ware" ceramics and are generally assumed to have been locally produced. Three gross categories of temper are found in these materials: mica and sand or schist temper in most sherds, and phyllite temper in a small percentage of sherds. The low frequency of phyllite tempered material suggested that it had been brought into the area from outside, while the remaining material was thought to have been locally manufactured (Abbott 1984). In order to test these assessments, 130 plain ware sherds were

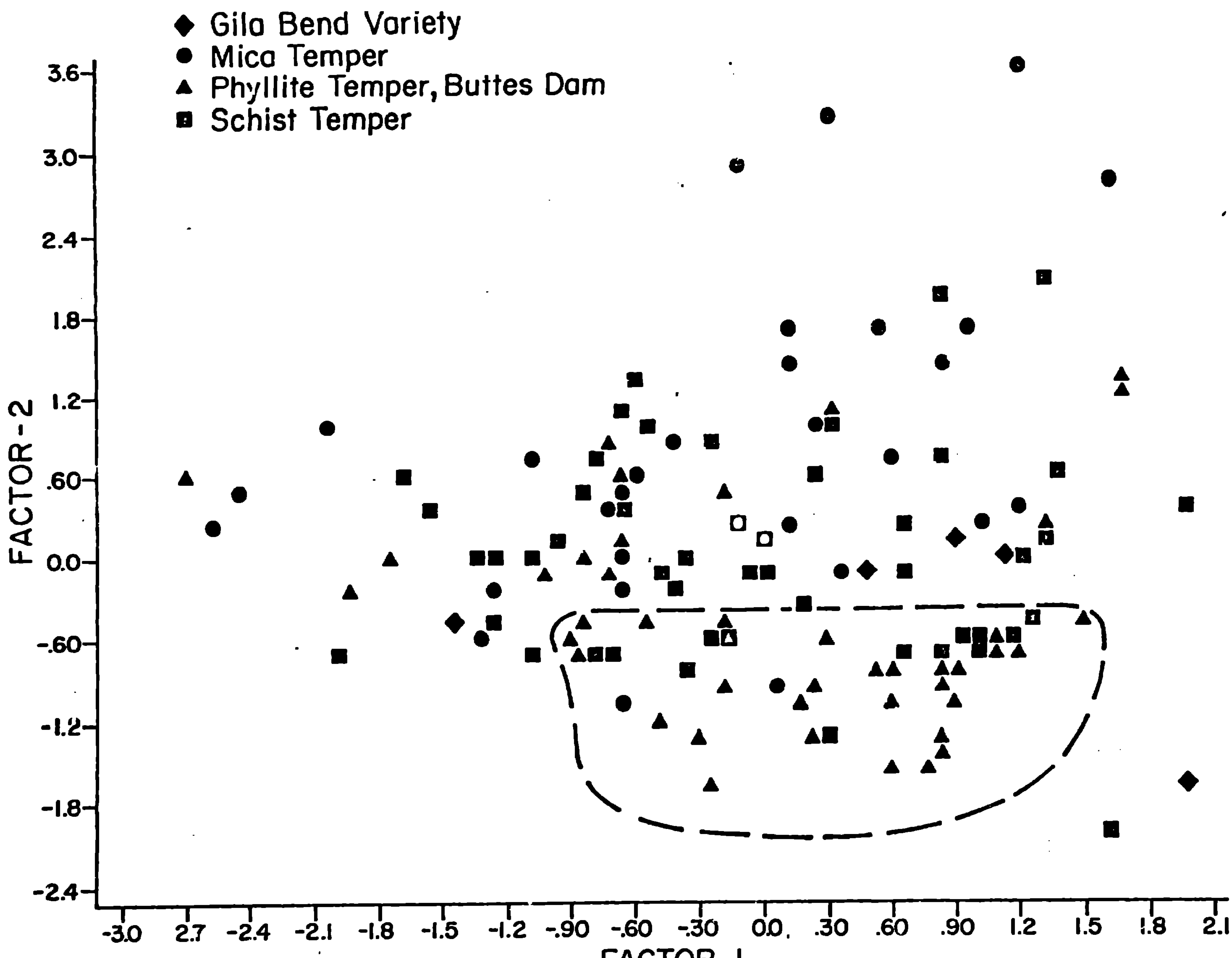


Figure 2. Plot of Factors 1 and 2 for plainware sherds from principal components analysis.

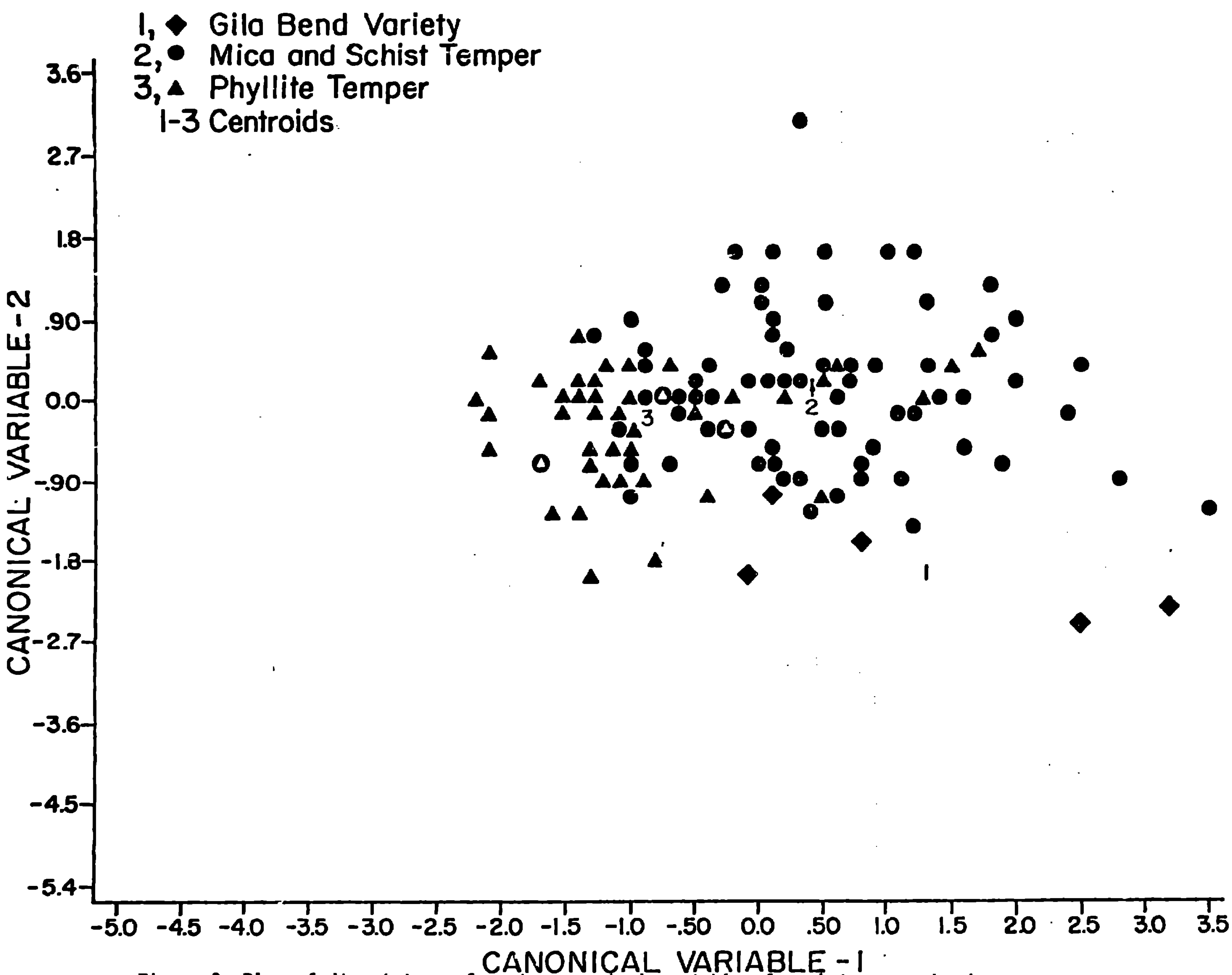


Figure 3. Plot of discriminant function canonical variables for plain ware sherds.

analyzed by XRF. In addition to sherds of the three basic temper categories, five sherds from a site outside of the Hohokam domain were analyzed for control. Only jar sherds were used in the analysis to eliminate any variability in clay types associated with vessel function.

The principal components analysis of 130 sherds derived six factors. Factor 1 was based primarily on iron, rubidium, yttrium, and zirconium, Factor 2 on strontium and calcium. These two factors explained 64% of the variance. A plot of these factors (Figure 2) shows phyllite-tempered material, primarily within the circle, clustered away from the micaceous and schist tempered material, which cluster together. Given these results, the discriminant function analysis used only three groups: sherds tempered with phyllite, the foreign sherds, and sherds tempered with either mica and sand or schist. Using the groupings noted, 69.2% of the sherds were correctly classified to assigned groups, as shown in the plot of the canonical variables (Figure 3).

The results suggest that the material tempered with phyllite was indeed made primarily from different clay sources than the material tempered with mica and sand or schist. As hypothesized, the mica and sand and schist-tempered materials were not distinct from one another, and the same sources were probably utilized in producing ceramics tempered with these rock types.

Evaluating Mode of Production of Red-on-buff Ceramics

An example of the use of XRF in exploring mode of production of Hohokam ceramics comes from our study of Hohokam ceramics with red designs on a buff firing clay produced between A.D. 700 and 1200. The assumption made in studies of mode of production is that pottery made by specialists or at a manufacturing center will be more homogeneous in chemical composition than that produced on a household or site level, since household or site production would involve a greater variety of manufacturing traditions and materials sources. When a site produces its own ceramics, we expect it to produce pots that are homogeneous chemically, but different from ceramics produced at other sites. When a single "center" produces ceramics for many sites and trades them to those sites, we expect the producer and recipient sites to yield ceramics that are chemically uniform. It has been suggested that the Hohokam decorated ceramics produced in the time period between A.D.900-1100 were mass-produced in quantities at a few manufacturing centers (Haury 1976; Doyel 1979; Abbott 1984). A recent petrographic analysis of Hohokam buff ware tended to support this model (Masse 1980: 144). In order to test the model further, 152 red-on-buff sherds from the time periods before, during and after this hypothesized era of ceramic mass-production were run. Sherds were drawn from a site believed to have been a ceramic manufacturing center, as well as numerous geographically dispersed smaller sites presumed to have been recipients of mass-produced vessels rather than manufacturing centers. If the change to mass-production had occurred, we would expect to see many sources during the early period, a drastic reduction in the number of materials sources during the middle period, and then a jump to a greater number of sources again in the late period. Only jar sherds with schist temper were run.

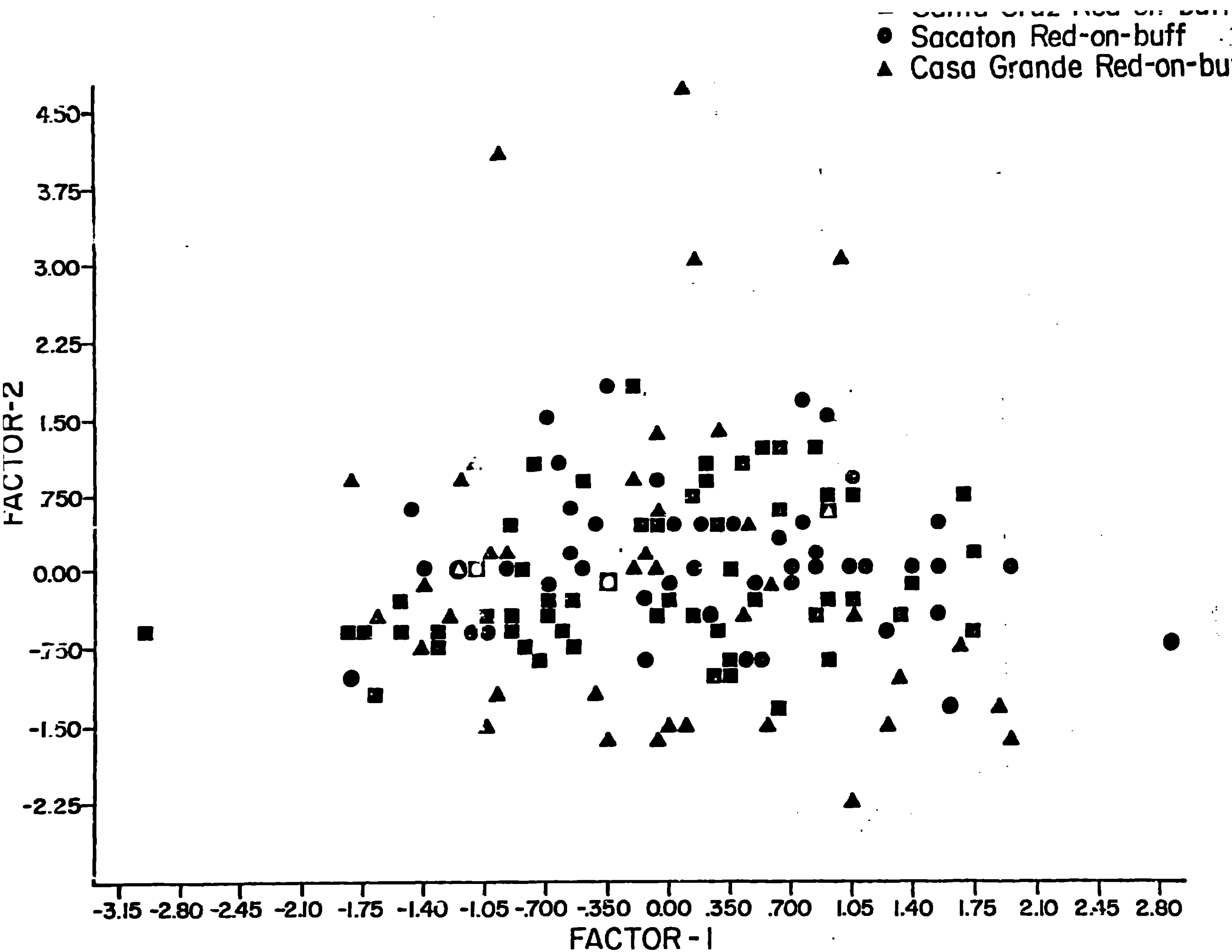


Figure 4. Plot of Factors 1 and 2 for buff ware sherds from principal components analysis.

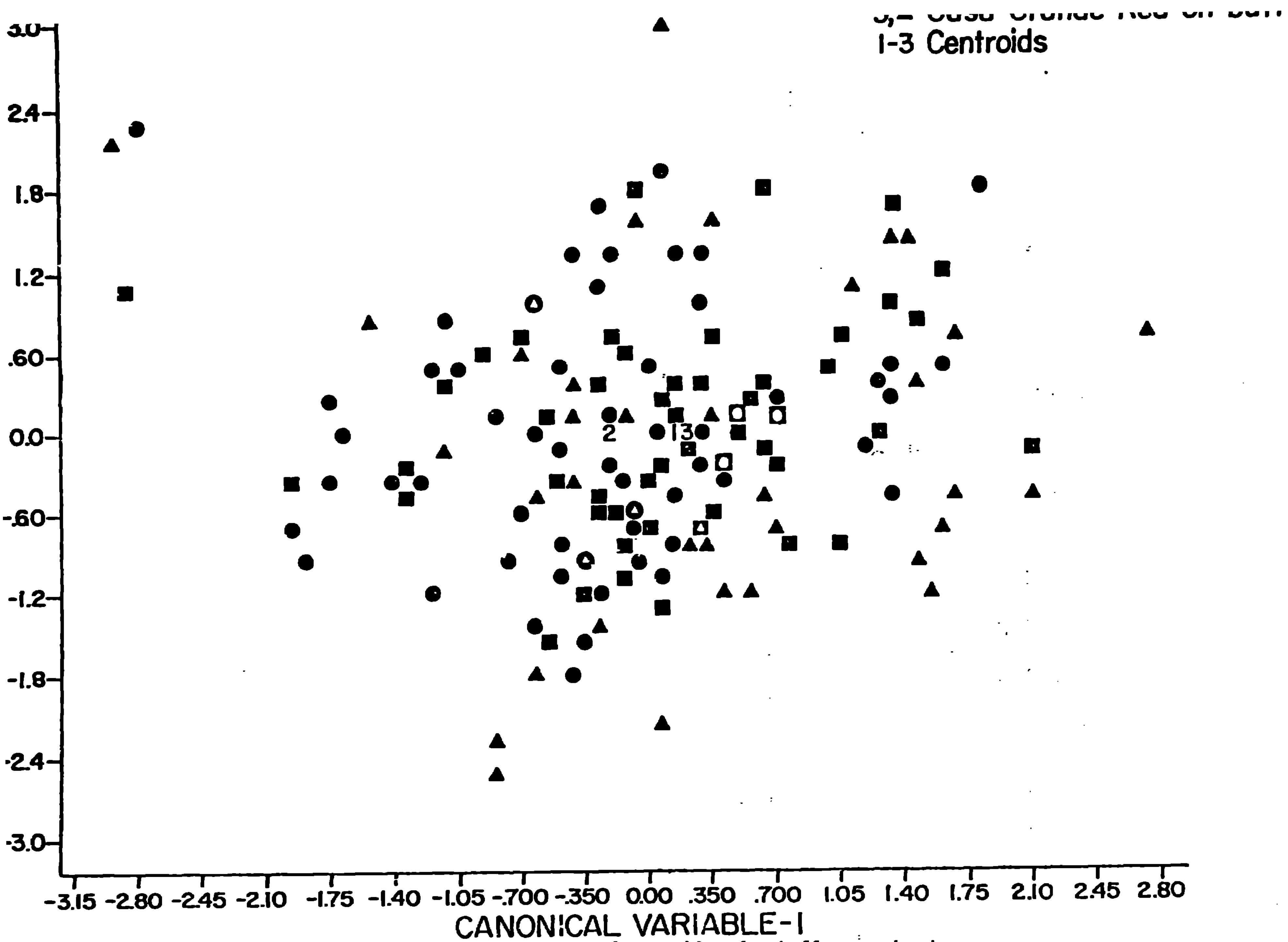


Figure 5. Plot of discriminant function canonical variables for buff ware sherds.

The principal components analysis derived six factors. Factor 1 was based primarily on iron, rubidium, yttrium, and zirconium; Factor 2 on strontium and calcium. These two factors explain 75% of the variance. Plots (Figure 4) of the sherd factor scores failed to show any clear clustering by ceramic type or by site. Instead the ceramics produced before (the squares) and during (the circles) the hypothesized period of mass-production are equally dispersed, with the later sherds (the triangles) showing the greatest dispersion, but still overlapping the earlier material. The absence of any clear clustering does not necessarily indicate that a single source is represented by all of this material. In fact, given the amount of dispersal, the assemblage is probably derived from multiple sources whose chemical distributions as transformed into factors overlap. A discriminant function analysis was performed using these same data, but only 43% of the samples were correctly classified to assigned group. A plot (Figure 5) of the samples using canonical variables from the analysis reveals no clear patterning.

On the basis of these results, it is not possible to indicate how many sources were in use by the Hohokam for red-on-buff ceramics during any time period. However, it is possible to state that there is no evidence to indicate that the number of sources of clays used to manufacture these ceramics changed during the period when ceramics are thought to have been mass-produced. Furthermore, there is no evidence that any single site, including the hypothesized manufacturing center, was characterized by the use of only a single source for all of its ceramics. While the results of this analysis are not as clear-cut as those of the plain ware analysis, they do provide initial characterization of the buff-firing clays and suggest avenues for further research. In addition, the study suggests that red-on-buff ceramic production was not as simply organized as mass production during a single period and local production during all other time periods.

Energy-dispersive XRF is an attractive technique for archaeologists because it is non-destructive and data are accumulated rapidly and inexpensively. It is thus possible to run large numbers of samples in a cost-effective manner, and our research has shown that large numbers of samples must be run in order to properly document the high degree of variability inherent in Southwestern ceramics. In this and many other studies, XRF has proven to be an extremely valuable tool for answering questions about the past.

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